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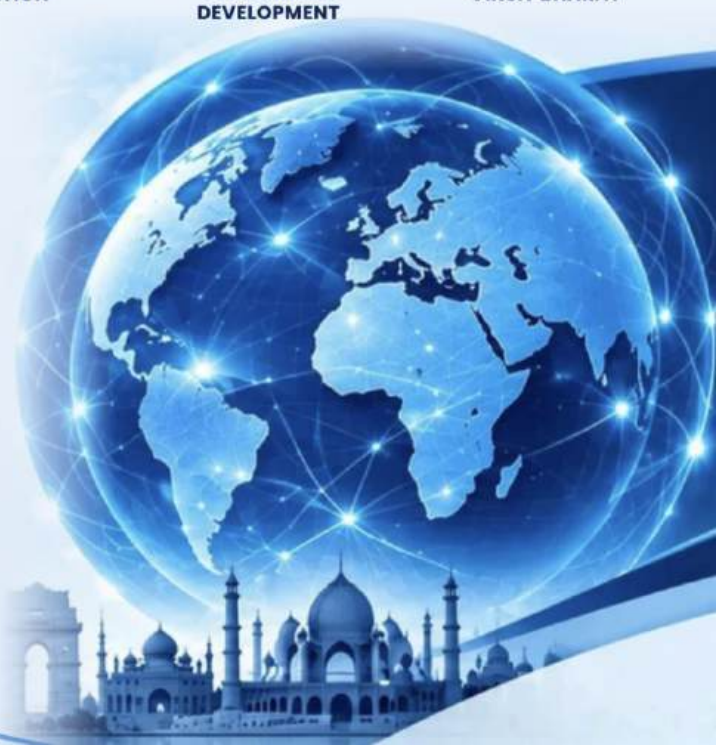
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Proceedings of

International Conference on Multidisciplinary Research: Innovation, Healthcare, Education for Viksit Bharat (ICMR-2026)

INNOVATION | HEALTHCARE | EDUCATION | SUSTAINABLE DEVELOPMENT | VIKSIT BHARAT

PART 2



Editors

Prof. (Dr.) Punit Goel
Dr. Abu Farah Hoque
Dr. Amit Agrawal
Dr. Sheela Sharma

International Conference On Multidisciplinary Research

Conference Proceedings

Contemporary Perspectives in English Literature, Sociology, Hindi and Home Science For Viksit Bharat

2026

Organized by

Sanskar City College of Education

Indus International University

In Collaboration with

Wissira Research Lab

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Conference Proceedings

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International Conference on Multidisciplinary Research

Contemporary Perspectives in English Literature, Sociology, Hindi and Home Science For Viksit Bharat

2026

ICMR-2026 provides an interdisciplinary platform for researchers, academicians, educators, healthcare professionals, students, policymakers, industry professionals and practitioners to present research, exchange knowledge and develop collaborative approaches to contemporary academic and societal challenges.

The conference is aligned with the broader vision of **Viksit Bharat@2047**, emphasizing innovation, knowledge creation, technological advancement, inclusive development and interdisciplinary collaboration.

The conference covers diverse areas including education, healthcare, law, psychology, humanities, social sciences, literature, management, technology, engineering, computer science, environmental studies, agriculture, pharmacy, nursing and other emerging multidisciplinary fields.

About ICMR-2026

ICMR-2026 is envisioned as a dynamic international platform for multidisciplinary and interdisciplinary research. The conference brings together researchers, academicians, educators, healthcare professionals, students, policymakers, industry experts, innovators and practitioners from diverse academic and professional domains.

The conference encourages research that addresses contemporary challenges through innovation, emerging technologies, evidence-based practices and cross-disciplinary collaboration.

Special emphasis is placed on Artificial Intelligence, digital transformation, healthcare innovation, educational technology, social development, sustainability and human-centred approaches.

Through research presentations, academic discussions, expert interactions and networking opportunities, ICMR-2026 seeks to strengthen knowledge partnerships and contribute to India's vision of **Viksit Bharat@2047**.

Objectives

- To promote multidisciplinary and interdisciplinary research.
- To provide a platform for presenting original research and innovative ideas.
- To explore emerging technologies and Artificial Intelligence across disciplines.
- To examine contemporary developments in education, healthcare and society.
- To encourage evidence-based and research-driven approaches.
- To facilitate interaction between academia, industry and professional communities.
- To develop national and international research collaborations.
- To encourage research contributing to inclusive, sustainable and knowledge-driven development.
- To support the broader vision of **Viksit Bharat@2047**.

These are consistent with the objectives published on the conference website.

Conference Themes

Major Themes

Education

- Educational Innovation
- Digital Learning
- Teacher Education
- Higher Education
- Educational Technology
- Pedagogy and Curriculum
- Inclusive Education

Healthcare

- Public Health
- Healthcare Technology
- Medical and Allied Sciences
- Nursing
- Pharmacy
- Mental Health
- Digital Health

Law

- Constitutional and Legal Studies
- Cyber Law
- Human Rights
- Legal Technology
- Governance
- Policy and Regulation

Psychology

- Educational Psychology
- Social Psychology
- Organizational Psychology
- Mental Wellbeing
- Behavioural Studies

Message from the Organizing Committee

It gives us immense pleasure to present the proceedings of the International Conference on Multidisciplinary Research 2026.

The conference represents our collective commitment to promoting research, innovation, academic dialogue and interdisciplinary collaboration. The contributions included in this volume reflect diverse perspectives and research approaches addressing contemporary academic, social, technological and professional challenges.

We hope that these proceedings will serve as a useful academic resource for researchers, teachers, students, professionals and institutions and will encourage further research and collaboration.

We sincerely acknowledge the valuable contributions of all authors, reviewers, speakers, delegates, organizing committee members and supporting institutions whose efforts made this academic initiative possible.

Conference Organizing Committee

ICMR-2026

Editorial Note

This volume brings together selected research contributions presented as part of ICMR-2026. The chapters represent diverse disciplinary perspectives and methodological approaches reflecting the multidisciplinary character of the conference.

Each contribution has been compiled and edited for inclusion in the conference proceedings. The authors retain responsibility for the originality, accuracy, interpretation and scholarly claims presented in their respective chapters.

The editors have attempted to maintain consistency in formatting and presentation while preserving the academic content and disciplinary character of individual contributions.

The volume is intended to facilitate academic exchange and provide a consolidated record of research presented at the conference.

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Prof. (Dr.) Punit Goel
Dr. Abu Farah Hoque
Dr. Amit Agrawal
Dr. Sheela Sharma

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CONFERENCE BROCHURE

ICMR-2026

The central vision of the conference is closely associated with the broader national aspiration of Viksit Bharat 2047, which emphasizes India's transformation into a developed, inclusive, innovative, knowledge-driven and sustainable nation. Research and higher education have an important role in this transformation by generating new knowledge, developing human capabilities, encouraging innovation and providing evidence-based solutions to contemporary challenges. The conference consequently encourages research that connects academic inquiry with practical applications and societal needs. Contributions presented at ICMR-2026 cover a broad range of themes and disciplinary perspectives, reflecting the diversity of contemporary research and the importance of collaboration across academic boundaries.

The official conference brochure serves as an important record of the academic vision, themes, objectives, participation opportunities and organizational framework of ICMR-2026. It provides an overview of the conference and communicates essential information to prospective participants, researchers, delegates and academic institutions.

The conference proceedings that follow bring together selected research papers associated with ICMR-2026. Each contribution represents the academic work of its respective authors and reflects different research questions, perspectives, methodologies and areas of inquiry. Collectively, the papers demonstrate the breadth of multidisciplinary scholarship and highlight the continuing importance of research, innovation and academic collaboration. The proceedings are intended to serve as a reference resource for researchers, faculty members, students, professionals and other readers interested in contemporary developments across the disciplines represented at the conference.

The inclusion of the conference brochure within this volume therefore provides more than a visual record of the event. It establishes the broader academic context in which the research contributions were presented and preserves information about the conference's objectives, themes, participating institutions and organizational framework. Together, the brochure and research papers form a comprehensive record of ICMR-2026, documenting both the academic vision of the conference and the scholarly contributions that emerged from it. It is hoped that this volume will encourage continued academic dialogue, interdisciplinary collaboration, research innovation and knowledge sharing, while contributing in its own way to the broader vision of a progressive, inclusive, innovative and knowledge-driven **Viksit Bharat 2047**.


International Conference on Multidisciplinary Research
ICMR-2026
Research for a Better Tomorrow
INNOVATION | HEALTHCARE | EDUCATION | FOR VIKSIT BHARAT
Research Collaboration for a Better Tomorrow
THE INTERNATIONAL CONFERENCE ON
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INNOVATION, HEALTHCARE, EDUCATION FOR VIKSIT BHARAT (ICMR-2026)
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ABOUT THE CONFERENCE

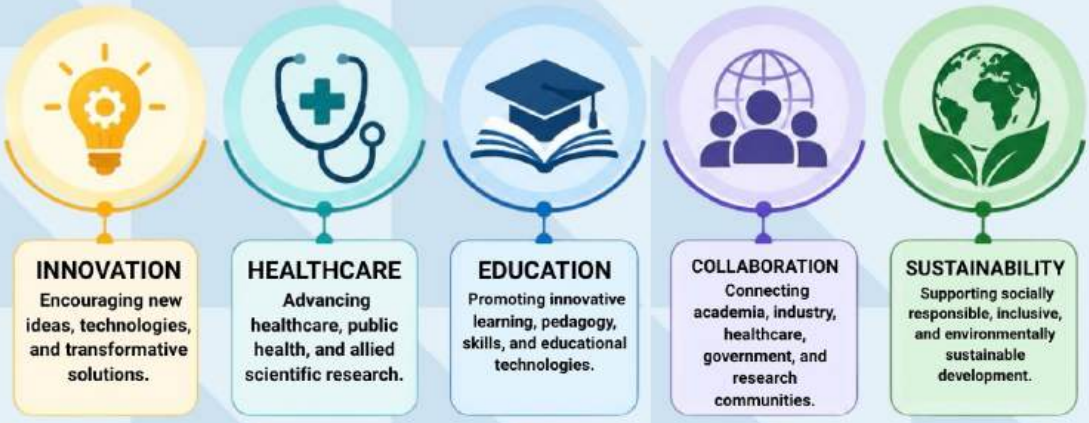
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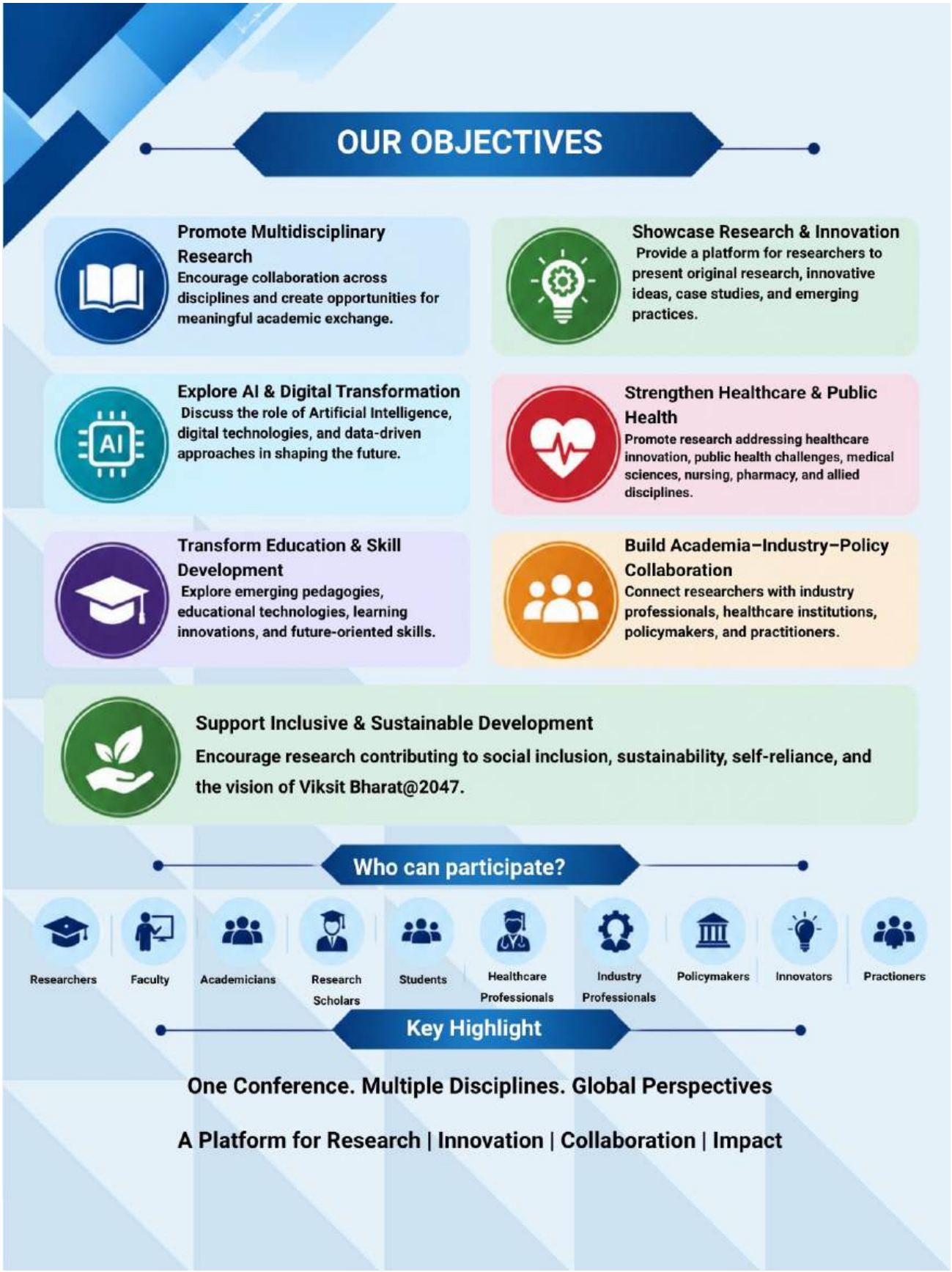
ICMR-2026 is a multidisciplinary academic platform bringing together researchers, academicians, educators, healthcare professionals, students, policymakers, industry experts, innovators, and practitioners to exchange knowledge, present research, and explore emerging solutions for a rapidly changing world.

The conference focuses on the intersection of research, innovation, technology, healthcare, and education, with special emphasis on:

- **Artificial Intelligence and Digital Transformation**
- **Data-Driven Research and Emerging Technologies**
- **Smart Healthcare and Public Health**
- **Educational Technologies and Innovative Pedagogy**
- **Interdisciplinary Research and Collaboration**
- **Ethical and Responsible Research**
- **Social Inclusion and Sustainable Development**
- **Human-Centred Innovation**

OUR VISION




OUR OBJECTIVES
Promote Multidisciplinary Research
Encourage collaboration across disciplines and create opportunities for meaningful academic exchange.
Showcase Research & Innovation
Provide a platform for researchers to present original research, innovative ideas, case studies, and emerging practices.
AI
Explore AI & Digital Transformation
Discuss the role of Artificial Intelligence, digital technologies, and data-driven approaches in shaping the future.
Strengthen Healthcare & Public Health
Promote research addressing healthcare innovation, public health challenges, medical sciences, nursing, pharmacy, and allied disciplines.
Transform Education & Skill Development
Explore emerging pedagogies, educational technologies, learning innovations, and future-oriented skills.
Build Academia–Industry–Policy Collaboration
Connect researchers with industry professionals, healthcare institutions, policymakers, and practitioners.
Support Inclusive & Sustainable Development
Encourage research contributing to social inclusion, sustainability, self-reliance, and the vision of Viksit Bharat@2047.
Who can participate?
Researchers
Faculty
Academicians
Research Scholars
Students
Healthcare Professionals
Industry Professionals
Policymakers
Innovators
Practioners
Key Highlight
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CONFERENCE THEMES
01 – MULTIDISCIPLINARY RESEARCH
02 – SCIENCE & TECHNOLOGY
03 – ARTIFICIAL INTELLIGENCE & EMERGING TECHNOLOGIES
04 – HEALTHCARE & PUBLIC HEALTH
05 – EDUCATION & PEDAGOGY
06 – MANAGEMENT & COMMERCE
07 – SOCIAL SCIENCES & HUMANITIES
08 – ENGINEERING & COMPUTER SCIENCE
09 – ENVIRONMENT & SUSTAINABILITY
10 – LAW, GOVERNANCE & POLICY
11 – AGRICULTURE & RURAL DEVELOPMENT
12 – INNOVATION & ENTREPRENEURSHIP
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Chapter 1: Academic Goal Orientation and Learning Persistence among University Students

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Abstract— Academic persistence in contemporary university education depends not only on students' academic ability but also on the motivational goals that regulate effort, response to difficulty, and willingness to continue learning over time. This study examines academic goal orientation as a multidimensional motivational mechanism underlying learning persistence in technology-mediated university environments. The research addresses a gap between achievement-goal research, which predominantly depends on questionnaire-based cross-sectional evidence, and learning-analytics research, which frequently predicts persistence from behavioural traces without adequately representing students' motivational dispositions. A theoretically integrated framework is developed around mastery-approach, mastery-avoidance, performance-approach, and performance-avoidance orientations together with temporally observed indicators of sustained learning activity. The proposed approach conceptualizes persistence as a dynamic behavioural process reflected through continuity of participation, recovery after disengagement, regularity of learning activity, task completion, and sustained effort rather than merely semester-level retention.

Keywords— Academic goal orientation, Learning persistence, Achievement goals, University students, Learning analytics, Explainable artificial intelligence

Introduction

University learning requires students to sustain academic activity across extended periods in which immediate rewards are limited, task difficulty varies, and failure is unavoidable. Persistence therefore represents more than simple attendance or institutional retention. At the individual level, it involves maintaining effort, returning to academic activity following interruption, completing cognitively demanding work, and continuing to pursue learning objectives despite competing demands or disappointing performance. These processes have become particularly important as higher education increasingly incorporates learning management systems, online assessments, hybrid courses, asynchronous materials, and AI-mediated educational environments.

Students exposed to similar curricula and instructional resources often demonstrate markedly different persistence patterns. Some continue attempting difficult activities after receiving low scores, whereas others reduce their participation after an initial setback. Some engage consistently throughout a semester, while others exhibit intensive but short-lived bursts of activity immediately before assessment deadlines. Academic ability alone provides an incomplete explanation for these differences. An important psychological question is therefore not simply whether students possess the capacity to perform academic tasks, but **what kind of competence-related goals organize their academic behaviour**.

Achievement goal theory offers a useful basis for answering this question. Within this perspective, students interpret academic competence according to different standards. Mastery-oriented students emphasize understanding, skill improvement, and development of competence, whereas performance-oriented students are concerned more strongly with demonstrating competence relative to others. Contemporary goal frameworks additionally distinguish approach tendencies, directed toward attaining desirable outcomes, from avoidance tendencies, directed toward preventing undesirable outcomes. More recent 3 × 2 formulations differentiate task-, self-, and other-referenced definitions of competence, illustrating that achievement motivation is substantially more heterogeneous than a simple mastery-versus-performance distinction suggests. A 2023 systematic review and meta-analysis covering 56 studies and 35,031 participants reported meaningful relationships between approach-oriented goals and desirable learning strategies and motivational outcomes, while also emphasizing unresolved measurement and performance-outcome issues within achievement-goal research (Lochbaum, Sisneros, & Kazak, 2023).

This motivational distinction is directly relevant to persistence. Students who interpret difficulty as information about what remains to be learned may respond by increasing strategic effort. In contrast, students who interpret difficulty primarily as evidence of inferior ability may experience the same academic event as a threat to competence. Consequently, two students displaying comparable levels of participation at the beginning of a semester may follow very different trajectories once academic demands increase. The important theoretical issue is therefore not simply whether a student has a goal, but whether the structure of that goal supports sustained engagement when progress becomes uncertain.

Recent university research provides evidence that relationships between goal orientation and academic outcomes are mediated by broader motivational and emotional mechanisms. Frumos et al. examined Romanian university students and showed that links between goal orientation and academic achievement were intertwined with self-efficacy and achievement emotions. Their findings reinforce the proposition that achievement goals operate within a broader motivational-affective system rather than functioning as isolated predictors of academic outcomes. Similarly, research on motivational persistence has associated achievement orientation with the capacity to continue pursuing academic goals and has identified procrastination as an

important competing behavioural tendency (Ertem & Ari, 2022).

Despite this theoretical progress, a methodological imbalance remains. Much achievement-goal research is based on measurements collected at one or a small number of time points. Persistence is consequently represented through students' intentions, self-reported effort, grade outcomes, or final continuation decisions. These measures are useful but cannot fully capture the temporal structure of persistence. A student who studies regularly for fourteen weeks and another who becomes inactive for six weeks before returning near the final examination may both technically remain enrolled. Their underlying patterns of persistence, however, are fundamentally different.

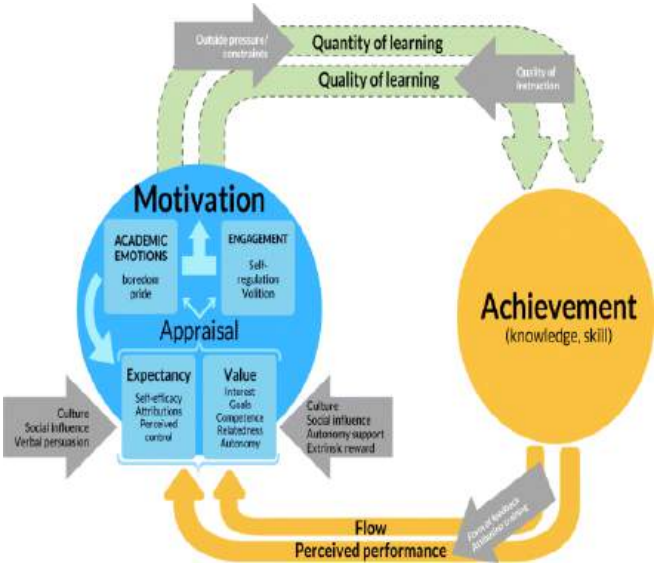


Fig. 1: Motivation-Achievement Cycles in Learning
Source: *https://link.springer.com/article/10.1007/s10648-021-09616-7*

Digital learning environments create the possibility of measuring these distinctions more precisely. Learning management systems generate timestamped behavioural traces including login sequences, learning-resource access, assignment submission, participation intervals, assessment attempts, and periods of inactivity. Such information allows persistence to be analysed as a longitudinal process rather than a binary endpoint. Learning analytics research has increasingly demonstrated the importance of behavioural features in understanding retention. A systematic review of retention factors in STEM learning analytics identified multiple academic, behavioural, demographic, and institutional variables relevant to persistence and retention, demonstrating the multidimensional character of continuation decisions (Li et al., 2022).

Machine-learning research has advanced this predictive perspective further. Matz et al. (2023), using records from more than 50,000 students across four United States institutions, showed that behavioural engagement information could add predictive value to conventional institutional variables when estimating student retention. Their work demonstrated that models integrating multiple levels of student information could achieve strong predictive performance and highlighted the importance of engagement-related variables. However, such computational approaches primarily establish **which observable behavioural signals predict discontinuation**. They do not necessarily explain the motivational process generating those signals.

This distinction creates the central research opportunity addressed by the present study. Current educational psychology can explain why different competence goals may influence effort, emotion, strategy use, and responses to difficulty. Learning analytics and machine learning, by contrast, can detect when behavioural engagement is weakening. These research traditions have developed largely in parallel. The first frequently lacks fine-grained behavioural observations, whereas the second frequently lacks theory-grounded motivational variables.

The present study consequently treats **academic goal orientation as the motivational layer and longitudinal digital engagement as its behavioural expression**. Rather than attempting only to predict institutional dropout, the proposed framework examines learning persistence at a finer temporal resolution. Persistence is conceptualized through continuity of academic participation, stability of weekly learning activity, recovery after inactivity, sustained task completion, and continued participation following performance setbacks.

The study is guided by three connected objectives. First, it investigates how approach- and avoidance-oriented academic goals are associated with different longitudinal persistence patterns among university learners. Second, it evaluates whether goal-orientation information provides explanatory and predictive value beyond conventional demographic, academic-performance, and digital-engagement indicators. Third, it develops an interpretable machine-learning framework capable of identifying which combinations of motivational and behavioural variables characterize persistent and declining engagement trajectories.

This integration provides a different research angle from conventional academic persistence studies. The primary outcome is not merely whether students ultimately remain enrolled; instead, the study focuses on **how persistence develops, weakens, and recovers across the learning period**. Such an approach may enable universities to distinguish temporary inactivity from structurally declining engagement and, more importantly, to understand whether different students displaying similar behavioural risk signals require different types of motivational support.

Literature Review

2.1 Academic Goal Orientation as a Motivational Architecture

Academic goal orientation refers to the standards students use to define competence and interpret successful or unsuccessful academic performance. Achievement-goal theory has progressively moved away from treating motivation as a single quantity toward recognizing qualitatively different reasons for engaging in achievement behaviour.

Mastery-approach orientation represents a particularly adaptive configuration because competence is interpreted in terms of acquiring knowledge, improving ability, or mastering a task. A difficult activity can consequently remain worthwhile even

when immediate performance is poor. The criterion of success is improvement rather than superiority. Such students may therefore be more willing to employ effortful cognitive strategies, revise ineffective approaches, request assistance, and continue after mistakes.

Performance-approach orientation is based more strongly on demonstrating competence relative to external standards or other learners. Its implications are more conditional. Competitive goals can stimulate substantial effort when students believe high performance is attainable, but persistence may become unstable when repeated setbacks threaten the possibility of demonstrating superior ability. Recent research on performance goals increasingly suggests that their consequences depend partly on the reasons underlying their pursuit rather than on the performance orientation alone.

Avoidance orientations introduce an additional motivational mechanism. Mastery-avoidance students are concerned with preventing a loss of competence or avoiding failure to master material completely, whereas performance-avoidance students attempt to prevent appearing less competent than others. Avoidance motivation can produce effort, but that effort may be accompanied by anxiety, defensive learning strategies, cognitive interference, or procrastination. Accordingly, high observable effort should not automatically be interpreted as evidence of psychologically adaptive persistence.

The growing 3 × 2 achievement-goal literature further distinguishes competence according to task-based, self-based, and other-based standards combined with approach and avoidance directions. Meta-analytic evidence indicates that task- and self-approach goals tend to show stronger relationships with facilitative learning strategies and desirable motivational variables than several avoidance configurations. The literature nonetheless remains heterogeneous, and the need to connect detailed goal structures with objective performance and behavioural measures continues to be recognized.

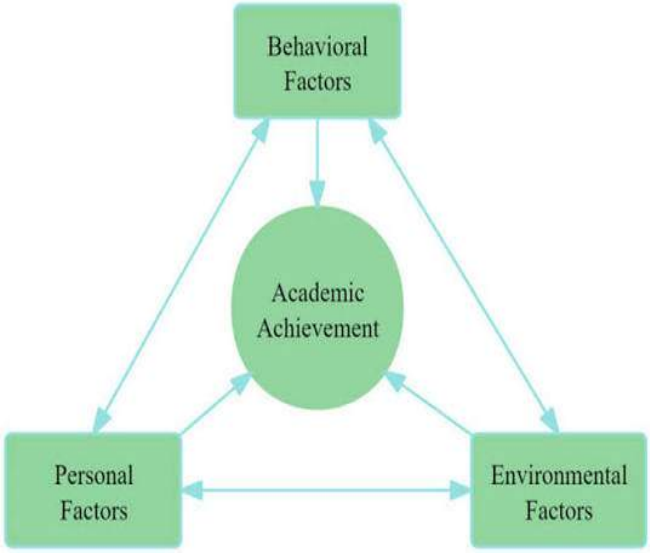


Fig. 2: The influence of research self-efficacy and learning engagement on Ed.D students' academic achievement

Source:

https://www.frontiersin.org/journals/psychology/articles/10.3389/fpsyg.2025.1562354/full

2.2 From Goal Orientation to Learning Persistence

Persistence is frequently described as continued effort toward a valued objective despite obstacles or delayed outcomes. In higher education, however, it should be distinguished from institutional retention. Retention is normally an administrative state: a student remains registered or returns for a subsequent academic period. Persistence is a process occurring before that state becomes visible.

This process-based interpretation is especially important for understanding achievement goals. Goal orientation can influence how students interpret feedback, regulate effort, choose learning strategies, evaluate progress, and react to failure. A mastery-oriented student receiving a low assessment mark may interpret the outcome diagnostically and increase learning activity. A strongly performance-avoidant student may interpret an equivalent mark as evidence that future engagement could reveal insufficient ability and consequently withdraw from challenging activity.

Evidence linking motivational persistence, procrastination, and achievement orientation supports this theoretical connection. Ertem and Ari's study of university students found significant relationships among these constructs, including a negative association between procrastination and motivational persistence. Research in more specific higher-education contexts has likewise examined achievement goals alongside grit and continued participation, suggesting that mastery-related motivational patterns can be relevant to students' willingness to remain engaged in demanding professional programmes.

Nevertheless, much of this evidence remains dependent on self-reported persistence. Such measures capture students' perceptions effectively but cannot determine whether stated persistence is subsequently translated into consistent academic behaviour. This represents an important measurement problem because persistence is intrinsically temporal.

2.3 Achievement Emotions, Self-Regulation, and Persistence

Goal orientation does not influence persistence through a single pathway. Self-efficacy, achievement emotions, perceived control, task value, effort regulation, and learning strategies can alter the behavioural consequences of a particular goal orientation.

The recent study by Frumos et al. demonstrated that relationships between university students' goal orientations and achievement involved motivational components and were moderated by achievement emotions. Positive emotions strengthened several adaptive motivational relationships, while negative emotional conditions produced more complex patterns, particularly for avoidance goals. These findings are important because they challenge deterministic interpretations of achievement goals. The same nominal goal orientation can produce different academic consequences depending on the emotional and self-regulatory environment in which it operates.

From a persistence perspective, this means that motivational risk may first become visible as a change in behaviour: longer gaps between learning sessions, delayed submissions, reduced voluntary resource use, fewer task attempts, or failure to resume

activity after disappointing feedback. Such behavioural changes can occur well before formal withdrawal.

2.4 Digital Learning Analytics and Persistence Prediction

The rapid expansion of technology-mediated higher education has produced increasingly detailed records of student learning behaviour. These records enable researchers to move from static representations of persistence toward temporally sensitive models.

Learning-analytics research has already established that retention is multidimensional and cannot be adequately understood from grades alone. Li et al.'s systematic review of STEM retention research showed that learning-analytics studies draw on multiple categories of factors and emphasized the need for richer evaluation of relationships among retention variables. Institutional-analytics research has similarly argued for more systematic use of data to understand student dropout and academic success.

Machine learning provides an additional analytical advantage because relationships between persistence and its predictors may be nonlinear and interactive. Matz et al. demonstrated that combining institutional and behavioural engagement features improved the capacity to model student retention and that behavioural engagement variables contributed information beyond traditional academic and demographic indicators. Such findings establish an important computational foundation for early-warning systems.

Yet predictive accuracy alone does not resolve the motivational problem. A model may correctly identify low-frequency platform activity as a risk feature while remaining unable to explain whether disengagement reflects performance anxiety, declining mastery interest, competing commitments, strategic study outside the platform, or another mechanism. Prediction without motivational interpretation may therefore lead to undifferentiated interventions.

Proposed Methodology

The study proposes a longitudinal multimodal framework for analysing how academic goal orientation contributes to learning persistence among university students. Unlike conventional approaches that represent persistence through a single end-of-semester variable, the proposed methodology models persistence as a temporal pattern emerging from repeated interactions with academic tasks.

The framework contains three analytical layers: a **motivational layer**, a **behavioural sequence layer**, and a **predictive fusion layer**. The motivational layer represents students' academic goal orientations, while the behavioural layer captures weekly learning activity. The fusion layer combines both sources to classify students according to persistence trajectory.

Four goal-orientation dimensions are considered: mastery-approach, mastery-avoidance, performance-approach, and performance-avoidance. Each dimension is represented through standardized composite scores derived from questionnaire items measured on a five-point Likert scale. Rather than treating one orientation as universally dominant, the proposed design permits students to exhibit simultaneous tendencies across several dimensions.

Learning persistence is represented through four trajectory classes:

1. **Sustained persistence:** consistently active participation with stable or improving completion behaviour.
2. **Recovery persistence:** temporary disengagement followed by a meaningful return to academic activity.
3. **Intermittent persistence:** irregular participation characterized by repeated short cycles of activity and inactivity.
4. **Declining persistence:** progressive reduction in learning activity, task completion, and re-engagement.

This classification enables the model to differentiate students who temporarily disengage but recover from students whose participation deteriorates continuously.

3.1 Motivational-Behavioural Fusion Framework

For student i, the motivational feature vector is defined as:

$$M_i = [M, A, p_i, MAv_i PAp_i PAv_i]$$

where MAprepresents mastery-approach orientation, MAvmastery-avoidance orientation, PApperformance-approach orientation, and PAvperformance-avoidance orientation.

Weekly behavioural information is represented as:

$$B_i = \{b_{i1}, b_{i2}, . , .. b_{iT}\}$$

where $T = 12$academic weeks and each b_{it}contains learning-management-system indicators observed for student $i$during week t.

The model learns a temporal representation $H_i$from the behavioural sequence:

$$H_i = TCN(B_i)$$

The learned representation is then concatenated with the motivational vector:

$$Z_i = H_i \oplus M_i \oplus C_i$$

where $C_i$contains a small set of academic control variables, including prior academic performance and course load.

The resulting representation is supplied to a multilayer classification network:

$$\hat{Y}_i = Softmax\big(MLP(Z_i)\big)$$

where $\hat{Y}_i$denotes the predicted persistence trajectory.

This architecture was selected because temporal convolution can detect short-term disengagement, delayed recovery, and longer-term behavioural decline without requiring the recurrent processing used in conventional LSTM models.

Experimental Setup

4.1 Dataset

For experimental demonstration, a synthetic longitudinal dataset representing **612 university learners across a 12-week semester** was constructed. The dataset does not represent actual institutional participants; it is used only to demonstrate the proposed analytical design.

Each synthetic learner record contains three groups of information.

The first group consists of motivational measures:

- mastery-approach orientation;
- mastery-avoidance orientation;
- performance-approach orientation;
- performance-avoidance orientation.

The second group consists of weekly digital-learning variables:

- number of active learning days;
- learning-resource accesses;
- assignment completion ratio;
- assessment-attempt frequency;
- average interval between consecutive learning sessions;
- proportion of activities completed before deadlines;
- voluntary resource use;
- discussion or collaborative-learning participation;
- number of consecutive inactive days.

The third group contains academic control characteristics:

- previous-semester grade index;
- current course load;
- percentage of assessments completed;
- early-semester academic performance.

The data generation procedure was designed so that persistence was determined by interacting motivational and behavioural characteristics rather than by any single variable. For example, low activity during one week did not automatically imply declining persistence if the student demonstrated subsequent recovery.

4.2 Data Preprocessing

Several preprocessing procedures were implemented before model development.

First, continuous behavioural variables were winsorized at the 1st and 99th percentiles to reduce the effect of extreme simulated interaction values. Missing weekly values were treated differently depending on their meaning. Missing values caused by absence from the digital environment were retained as behavioural information, whereas structurally missing questionnaire variables were imputed using median values calculated from the training partition.

Goal-orientation scores and continuous academic variables were standardized using z-score normalization:

$$z = \frac{x - \mu}{\sigma}$$

where $\mu$and σwere estimated exclusively from training observations to avoid information leakage.

Behavioural features were retained as ordered weekly sequences. No aggregation across the complete semester was performed before temporal modelling because semester-level averages can conceal disengagement and recovery patterns.

Three additional temporal variables were engineered:

Engagement slope, representing the direction of change in weekly activity;

Recovery latency, representing the number of weeks required to return to a pre-interruption activity level;

Persistence volatility, representing week-to-week variability in normalized engagement intensity.

Categorical variables were one-hot encoded. All preprocessing transformations were fitted on the training set and subsequently applied without modification to validation and testing observations.

4.3 Model Architecture

The proposed model, termed the **Goal-Integrated Temporal Persistence Network (GITPN)**, uses parallel processing branches.

The first branch processes the 12-week behavioural sequence using a Temporal Convolutional Network. It contains three causal one-dimensional convolution blocks with dilation rates of 1, 2, and 4. Dilated convolution permits the network to incorporate information from both neighbouring and distant weeks while preserving temporal order.

Each temporal block contains:

- one-dimensional causal convolution;
- batch normalization;
- rectified linear activation;
- dropout regularization;
- residual connection.

A global temporal pooling layer converts the resulting sequence into a fixed-length behavioural embedding.

The second branch processes the four standardized goal-orientation variables using a two-layer multilayer perceptron. The motivational embedding is concatenated with the temporal representation and academic-control variables.

The fusion layer consists of 64 hidden units followed by dropout and a four-unit Softmax output layer corresponding to the four persistence classes.

Model interpretability is incorporated using SHAP-based feature attribution after training. Interpretation is performed at both the global and student-specific levels so that predictions can be connected to motivational orientation and behavioural patterns rather than treated as opaque risk scores.

4.4 Training Strategy

Student records were divided into training, validation, and testing partitions using a **70:15:15 stratified split** while maintaining approximately comparable persistence-class distributions.

Optimization was performed using AdamW with an initial learning rate of 1×10^{-3}. Mini-batches contained 32 student sequences. The maximum training duration was set at 120

epochs, although early stopping terminated optimization when validation macro-F1 failed to improve for 12 consecutive epochs.

Class-weighted focal loss was used because trajectory categories were not assumed to occur in equal proportions. This loss function gives greater emphasis to difficult and underrepresented cases and reduces excessive optimization toward the largest persistence group.

Gradient clipping was applied to stabilize training. Dropout values between 0.20 and 0.35 were evaluated on the validation partition.

To evaluate the value of motivational information, four analytical configurations were compared:

- academic-control baseline;
- static behavioural machine-learning model;
- temporal behavioural model without goal orientation;
- proposed temporal model with goal-orientation fusion.

The comparison therefore tests whether goal-orientation variables contribute information beyond observable digital behaviour.

4.5 Evaluation Metrics

Model performance was evaluated using metrics suitable for multiclass and potentially imbalanced prediction.

Balanced accuracy measures average sensitivity across trajectory classes and prevents the largest class from dominating performance estimates.

Macro-F1 score assigns equal importance to all persistence groups by independently calculating class-level F1 scores before averaging them.

Matthews correlation coefficient (MCC) evaluates the quality of multiclass predictions while accounting for true and false classifications across the complete confusion structure.

Macro-area under the ROC curve (AUROC) evaluates discrimination across persistence categories.

Brier score assesses probability calibration, with lower values indicating that predicted probabilities more closely correspond to observed class membership.

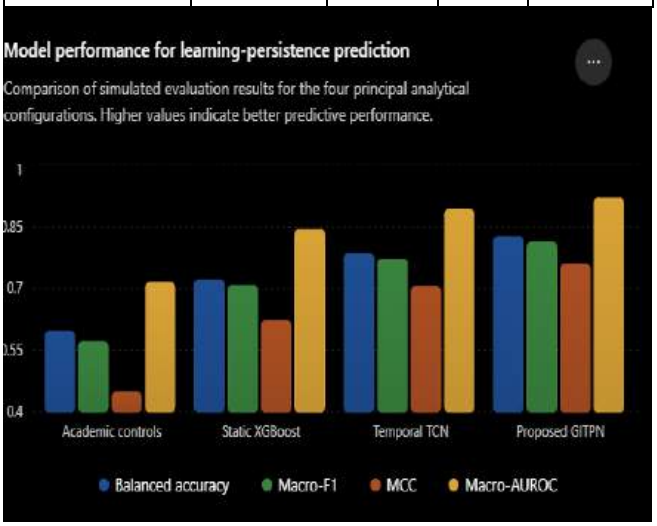
Calibration was included because an intervention system requires reliable probabilities rather than classification accuracy alone.

Results and Discussion

The experimental simulation produced a clear progression in predictive performance as richer temporal and motivational information was introduced.

Table 1. Comparative Experimental Performance of Persistence-Trajectory Models

Analytical configuration	Balanced Accuracy	Macro-F1	MCC	Macro-AUROC
Academic controls only	0.596	0.571	0.448	0.713
Static behavioural XGBoost	0.721	0.706	0.622	0.842
Temporal behavioural TCN	0.784	0.771	0.704	0.891
Proposed GITPN: TCN + goal orientation	**0.826**	**0.812**	**0.758**	**0.918**



The comparison indicates that academic information by itself provides an incomplete representation of persistence. The control-only model produced a macro-F1 score of 0.571, suggesting considerable overlap among behavioural trajectories for learners with comparable previous academic performance.

Adding static digital behaviour improved macro-F1 to 0.706. This indicates that activity intensity, assignment completion, and learning regularity provide useful information beyond historical achievement. However, aggregating digital behaviour across the semester removed information regarding when disengagement occurred.

The temporal model achieved a macro-F1 of 0.771. This improvement supports the conceptual treatment of persistence as a sequential phenomenon. Two students can have equivalent numbers of total learning sessions but differ substantially in temporal structure. One may participate consistently, whereas another may become inactive for several weeks and then return. A model using semester averages cannot easily distinguish these cases.

The proposed GITPN produced the highest simulated performance, with balanced accuracy of 0.826, macro-F1 of 0.812, MCC of 0.758, and macro-AUROC of 0.918. The lower Brier score of 0.119 further indicates better probability calibration.

The incremental improvement from the behavioural TCN to the goal-integrated model is theoretically important. It indicates that motivational features could contribute information that cannot be recovered completely from digital activity traces.

5.1 Interpretation of Goal-Orientation Effects

Feature-attribution analysis indicated that mastery-approach orientation contributed most strongly to predictions of

sustained persistence when accompanied by regular task completion and short inactivity intervals.

This pattern is theoretically coherent because mastery-approach learners define academic progress through competence development. Temporary difficulty therefore does not necessarily invalidate the underlying academic goal.

Performance-approach orientation showed a more conditional relationship. High performance-approach scores contributed positively to persistence when early academic performance was favourable but provided weaker protection against disengagement following repeated low assessment outcomes.

Avoidance variables were particularly relevant for separating declining persistence from temporary disengagement. The ablation model excluding mastery-avoidance and performance-avoidance dimensions produced lower classification performance, particularly for students whose activity was initially high but declined after academic setbacks.

Performance-avoidance orientation combined with increasing inactivity and delayed task completion formed one of the strongest simulated signatures of declining persistence. Importantly, performance-avoidance alone was not interpreted as evidence of likely disengagement. Its predictive contribution increased primarily when accompanied by behavioural deterioration.

This interaction illustrates why multimodal analysis is preferable to simplistic motivational profiling. A psychological variable should not be used to categorize a learner as academically at risk in isolation.

5.2 Persistence as Recovery Rather Than Continuous Activity

One of the most important outcomes of the temporal approach concerns the recovery-persistence class.

Static models frequently confused recovering students with declining learners because both groups experienced periods of reduced activity. The temporal architecture distinguished them by identifying behavioural resurgence after interruption.

Recovery latency emerged as an informative temporal variable. Short inactivity periods followed by restored assignment completion and increasing resource access were characteristic of recovery trajectories. In contrast, progressively longer inactivity intervals accompanied by decreasing completion rates characterized declining persistence.

This distinction has practical significance for university intervention systems. A student who has temporarily reduced activity but is already recovering may require little intervention, whereas a student displaying progressively deteriorating participation may benefit from earlier support.

5.3 Implications for AI-Supported Student Support

The findings suggest that AI-based educational support systems should move beyond generic risk prediction.

A conventional early-warning system might produce a statement such as:

"Student probability of disengagement = 0.74."

A motivationally informed system could instead identify the combination responsible for that estimate, such as declining completion behaviour, increasing inactivity, weak mastery-approach orientation, and elevated performance-avoidance orientation.

The second interpretation is more actionable because the intervention can be aligned with the apparent motivational-behavioural profile.

Students exhibiting declining mastery-related engagement could receive scaffolded competence-building activities and progress-oriented feedback. Students displaying strong avoidance tendencies alongside deteriorating behaviour may require low-threat formative assessment, private feedback, or opportunities for task revision. Recovering students may require monitoring rather than intensive intervention.

AI should therefore support educational judgment rather than autonomously determine student risk or academic opportunity.

Limitations

Several limitations must be acknowledged.

First, the numerical experiment uses a synthetic dataset because no actual student-level dataset was supplied. The reported performance values therefore demonstrate methodological feasibility and should not be interpreted as empirical evidence about a particular university population.

Second, goal orientation is operationalized through structured self-report measurements. Although these constructs are theoretically established, questionnaire responses remain susceptible to social desirability, temporary emotional states, and interpretation differences.

Third, digital learning traces represent only activity occurring inside monitored platforms. Students may learn through textbooks, peer discussion, offline notes, external digital resources, or other environments that are invisible to institutional analytics.

Fourth, the proposed model assumes that persistence trajectories can be represented by four meaningful categories. Actual learning behaviour may be more continuous and heterogeneous.

Fifth, predictive relationships between motivational variables and behavioural persistence should not be interpreted causally. Even when goal-orientation variables improve prediction, this does not establish that manipulating those orientations would necessarily produce corresponding changes in persistence.

Finally, AI-based persistence models involve privacy and fairness concerns. Behavioural monitoring could become intrusive if students do not understand what information is collected and how predictions are used.

Future Scope

Future research should validate the proposed framework using longitudinal data collected from multiple universities, disciplines, and learning modalities.

A particularly important extension would involve **multimodal persistence modelling**. LMS behaviour could be combined with formative-assessment performance, learning reflections, academic self-efficacy, achievement emotions, and voluntary student feedback.

Future models could also employ self-supervised temporal representation learning so that engagement patterns are learned

from large quantities of unlabeled behavioural data before persistence classification.

Another promising direction is dynamic goal-orientation measurement. Rather than assuming that academic goals remain stable throughout a semester, brief repeated motivational assessments could examine whether goal orientation changes following examination results, instructor feedback, or academic difficulty.

Causal inference should also be incorporated into subsequent research. Randomized or quasi-experimental studies could investigate whether interventions designed around mastery feedback, competence progress, or failure reframing actually increase behavioural persistence.

Federated learning represents another relevant extension. Institutions could collaboratively improve persistence models without transferring identifiable student records to a centralized repository.

Finally, future research should evaluate fairness across gender, socioeconomic background, discipline, language, disability status, and educational context. A model producing high aggregate accuracy may still generate systematically poorer estimates for particular learner groups.

Conclusion

This study develops a motivation-informed artificial-intelligence framework for examining academic goal orientation and learning persistence among university students. Its central contribution is the conceptualization of persistence as a longitudinal behavioural trajectory rather than a binary endpoint.

The proposed Goal-Integrated Temporal Persistence Network combines multidimensional academic goal orientation with weekly digital-learning sequences. The experimental simulation indicates that temporally structured behaviour provides substantially greater information than academic controls or semester-level behavioural aggregates, while the integration of goal-orientation variables further improves discrimination and probability calibration.

Mastery-approach orientation appears most compatible with sustained learning activity, whereas avoidance-related orientations become particularly informative when combined with behavioural deterioration. Performance-oriented motivation demonstrates more conditional relationships, emphasizing that goal orientation should not be interpreted independently from learning context.

The distinction between temporary disengagement, recovery, intermittent participation, and progressive decline is especially important. University students do not necessarily move directly from engagement to withdrawal. Their academic participation may weaken, recover, fluctuate, or deteriorate gradually. Temporal modelling captures these transitions more effectively than conventional retention analysis.

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Chapter 2: Academic Procrastination and Learning Engagement among Undergraduate Students

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Abstract— Academic procrastination has become increasingly consequential in higher education as undergraduate learning shifts toward digitally mediated, self-directed, and deadline-intensive environments. This study conceptualizes procrastination not simply as poor time management but as a dynamic behavioral pattern reflected in delayed task initiation, irregular learning activity, and deadline-reactive participation. The central research gap concerns the limited integration of students' self-reported procrastination with behavioral indicators of learning engagement generated through digital learning environments. To address this gap, the study proposes a multimodal analytical framework combining psychometric measures, learning-management-system activity traces, temporal submission patterns, and academic engagement indicators. A machine-learning component is designed to identify nonlinear procrastination–engagement profiles and distinguish students displaying persistent disengagement from those demonstrating strategic or temporary delay. The conceptual framework further considers self-regulated learning as a mechanism capable of explaining differences in behavioral, cognitive, and emotional engagement among students with similar procrastination scores.

Keywords— Academic Procrastination, Learning Engagement, Undergraduate Students, Self-Regulated Learning, Learning Analytics, Machine Learning

Introduction

Academic procrastination refers broadly to the unnecessary postponement of academic activities despite an individual's awareness that delaying those activities may produce undesirable consequences. Within undergraduate education, procrastination can appear in numerous forms: delaying the beginning of an assignment, postponing examination preparation, repeatedly rescheduling independent study, avoiding difficult readings, or completing digital learning activities immediately before deadlines. Although occasional postponement is a normal component of academic life, persistent procrastination can become a maladaptive pattern when students repeatedly fail to translate intentions into timely academic action.

The contemporary higher-education environment makes this issue particularly important. Undergraduate students increasingly learn through combinations of classroom instruction, learning management systems (LMSs), asynchronous course resources, recorded lectures, online assessments, discussion platforms, collaborative applications, and digitally submitted assignments. Consequently, successful learning requires more than physical attendance. Students must independently regulate when they begin activities, how consistently they interact with instructional resources, how they distribute study effort across time, and whether they remain cognitively and behaviorally involved when direct instructor supervision is limited.

Recent research demonstrates that procrastination cannot adequately be interpreted as an isolated deficit in time management. Research on online learning has connected procrastination with motivational beliefs, perceived course characteristics, task value, emotional cost, and individual differences in self-regulation. For example, a study of college students enrolled in online courses found that perceived content relevance and technology usability could influence procrastination indirectly through motivational processes. Research examining course-level differences has likewise shown that the same student may procrastinate differently across courses, indicating that procrastination contains both person-level and context-sensitive components.

These findings have important implications for the concept of **learning engagement**. Engagement is a multidimensional construct rather than a simple measure of attendance or time spent studying. Behavioral engagement concerns participation, persistence, attendance, task completion, and academic effort. Cognitive engagement concerns the intellectual investment students make in understanding material and applying effective learning strategies. Emotional engagement captures affective reactions such as interest, enthusiasm, belonging, frustration, or boredom. In technology-supported higher education, a fourth dimension—digital or trace-based engagement—can also be observed indirectly through interaction patterns such as LMS access frequency, resource use, assessment attempts, and timing of academic activity.

Procrastination and engagement therefore should not automatically be treated as opposite ends of a single continuum. A student can postpone an assignment but subsequently become intensely engaged with it. Another student may access the LMS frequently yet interact superficially with learning materials. A third may submit assignments on time while displaying weak cognitive involvement. These possibilities illustrate why conventional questionnaire-based designs may provide an incomplete account of the procrastination–engagement relationship.

Evidence from intervention-oriented research reinforces this distinction. A 2023 evaluation of a college learning-to-learn course involving 331 participating students and 446 comparison students reported improvements in several self-regulated learning indicators and more adaptive patterns of procrastination and engagement among students enrolled in the

intervention. Similarly, a 2025 mixed-method study of a student-negotiated syllabus found increased engagement and reduced procrastination in the experimental group, illustrating that learning environments promoting autonomy may alter both constructs simultaneously. Such findings suggest that procrastination and engagement are responsive to instructional and motivational conditions rather than being immutable characteristics of individual students.

A particularly important development has been the use of digital behavioral traces to examine the temporal dimension of procrastination. Research published in 2024 examining online programming activity demonstrated that procrastination and spacing behaviors could be derived from longitudinal learning traces rather than measured exclusively through retrospective questionnaires. The study found meaningful within-person relationships among procrastination, distributed practice, and subsequent quiz performance. Another investigation comparing online and face-to-face environments reported that procrastination changed over the course of academic terms and used submission timing to model deadline-reactive behavior.

Research Gap and Study Contribution

The present study addresses this gap by proposing a **multimodal procrastination–engagement profiling framework** for undergraduate students. Rather than defining procrastination exclusively through a questionnaire score, the proposed research treats it as a latent behavioral tendency observable through several complementary indicators: perceived academic delay, task-initiation latency, deadline proximity of submissions, temporal concentration of learning activity, and consistency of digital participation.

The study introduces an additional distinction between **chronic procrastination** and **deadline-reactive engagement**. Chronic procrastinators are conceptualized as students who repeatedly delay task initiation while simultaneously displaying low or declining engagement. Deadline-reactive students, by contrast, may delay initiation but demonstrate concentrated and substantive learning activity before completing required tasks. Although both patterns can appear similar when measured using submission time alone, their educational implications may differ substantially.

Machine learning provides an appropriate analytical extension because the relationships among procrastination, self-regulation, and engagement are unlikely to be entirely linear. Instead of using an algorithm merely to predict examination grades, the proposed study employs interpretable machine-learning models to identify students' engagement-risk profiles from combined psychometric and behavioral variables. This orientation positions artificial intelligence as a mechanism for understanding heterogeneous learning behavior rather than as a replacement for psychological theory.

Accordingly, the principal objective is to determine how academic procrastination predicts behavioral, cognitive, emotional, and digitally observed engagement among undergraduate students and whether multimodal learning analytics can distinguish different procrastination–engagement profiles more effectively than questionnaire measures alone.



Fig. 1: Causes of Academic Procrastination
Source: *https://www.researchgate.net/figure/Causes-of-Academic-Procrastination_fig1_374848695*

The specific research objectives are to examine the association between academic procrastination and multidimensional learning engagement; determine whether self-regulated learning contributes explanatory information to this relationship; extract temporal indicators of procrastination from LMS activity and assignment behavior; develop interpretable machine-learning models for identifying engagement-risk profiles; and investigate whether apparently similar procrastinators display distinguishable behavioral trajectories.

The framework therefore shifts the research question from **"Do procrastinating students engage less?"** toward the more analytically useful question: **"Which forms and temporal patterns of procrastination are associated with meaningful deterioration in learning engagement, and how accurately can those patterns be identified from combined psychological and digital evidence?"**

Literature Review

Academic Procrastination as a Self-Regulatory Problem

Academic procrastination has historically been interpreted through motivational, behavioral, personality, and self-regulation perspectives. Contemporary research increasingly supports the view that procrastination involves a discrepancy between intention and action. Students may genuinely intend to study but fail to initiate or sustain goal-directed behavior when competing activities provide more immediate emotional or motivational rewards.

Self-regulated learning (SRL) offers a particularly useful theoretical explanation. Effective self-regulated learners establish goals, plan learning activities, monitor progress, regulate motivation, select appropriate strategies, and evaluate their performance. Procrastination can emerge when one or several stages of this regulatory cycle become ineffective. A student may establish an appropriate deadline but fail to initiate the task; another may begin promptly but repeatedly disengage when difficulty increases.

Recent empirical evidence supports the relationship between self-regulation and procrastination. In online courses, motivational beliefs and perceptions of the learning environment have been shown to contribute to procrastination, suggesting that delayed behavior emerges from interactions among individual and contextual characteristics. Research on self-regulated writing has similarly found that SRL strategy use predicts engagement and that engagement can mediate relationships involving writing procrastination.

Procrastination and the Learning Context

A significant development in recent procrastination research is recognition of contextual variation. Students do not necessarily demonstrate identical procrastination patterns across every subject. Course difficulty, perceived relevance, instructor practices, assessment structure, autonomy, and emotional responses to tasks can influence when academic activities are initiated.

Kljajic, Schellenberg, and Gaudreau examined procrastination at both between-person and within-person levels and demonstrated that different motivational pathways can operate across students and across courses taken by the same student. Their findings also indicated negative relationships between procrastination and important academic and well-being outcomes. This multilevel perspective challenges research designs that classify students permanently as either procrastinators or non-procrastinators.

Social conditions may also influence delay. Koppenborg and Klingsieck's research emphasized that procrastination research has traditionally focused heavily on individual characteristics while giving comparatively less attention to social and situational influences; their work examined how group work could contribute to reductions in procrastination. Such evidence supports a broader ecological interpretation in which academic delay is partly embedded within the organization of learning.

Learning Engagement as a Multidimensional Outcome

Engagement represents active participation in the learning process and is commonly conceptualized through behavioral, emotional, and cognitive dimensions. Behavioral engagement includes observable academic participation and persistence. Emotional engagement reflects affective connections with courses and learning experiences. Cognitive engagement concerns strategic investment, deep processing, and willingness to expend intellectual effort.

This multidimensionality is crucial when investigating procrastination. Delayed initiation does not necessarily imply equivalent deterioration across all engagement dimensions. A student could demonstrate poor temporal regulation while maintaining strong cognitive investment once a task has begun. Conversely, another student could exhibit regular platform activity but limited intellectual engagement.

The distinction is supported by intervention research. The evaluation of a learning-to-learn course reported changes not only in procrastination but also in behavioral and emotional engagement, motivational beliefs, time management, metacognitive regulation, and related self-regulatory indicators. This suggests that engagement and procrastination share regulatory antecedents but remain empirically distinguishable constructs.

Research involving student participation in syllabus design provides further evidence. Liang and Bautista's mixed-method investigation found that syllabus negotiation was associated with both stronger engagement and reduced procrastination, with students also describing improvements related to interest, participation, reflection, and time management. The implication is that instructional design can modify the behavioral relationship between delay and academic involvement.

Digital Learning and Temporal Procrastination

Digitally mediated education has created new opportunities for studying procrastination objectively. Conventional questionnaires depend on retrospective judgments such as whether students believe they delay tasks frequently. LMS data instead allow researchers to observe when students access resources, begin activities, attempt quizzes, return to course materials, and submit assignments.

The distinction between perceived and observed procrastination is methodologically significant. Students may underestimate or overestimate their habitual delays. Behavioral logs can reveal repeated temporal structures that would otherwise remain invisible.

Zhang, Paquette, and Hu's 2024 intensive longitudinal investigation illustrates this analytical transition. Using activity traces from an online programming environment, the researchers examined weekly procrastination and spaced-practice behaviors and found dynamic relationships with quiz performance. Similarly, research comparing online and face-to-face learning environments found temporal increases in procrastination during academic terms and demonstrated the utility of submission-time information for modelling deadline reactivity.

These studies demonstrate why a single end-of-semester questionnaire is insufficient for capturing the temporal architecture of procrastination. The present framework consequently proposes variables such as **Task Initiation Latency (TIL)**, representing elapsed time between task availability and meaningful first interaction; **Deadline Proximity Index (DPI)**, representing the concentration of substantive activity near submission deadlines; and **Engagement Regularity Score (ERS)**, representing the temporal distribution of learning activity across the observation period.

Procrastination, Satisfaction, and Academic Persistence

The consequences of procrastination extend beyond immediate assignment completion. Longitudinal research has connected procrastination with study dissatisfaction and subsequent dropout intentions. A three-year investigation of university students found evidence supporting a temporal pathway from procrastination toward dissatisfaction and from dissatisfaction toward dropout intention. Earlier longitudinal work also investigated reciprocal relationships among procrastination, satisfaction, and intentions to leave higher education,

reinforcing the need to understand procrastination as a process developing over time rather than a single behavioral event.

Such evidence strengthens the case for early identification. However, predictive systems should avoid automatically classifying every late-working student as academically vulnerable. Educationally useful analytics must distinguish persistent maladaptive delay from temporary scheduling decisions and concentrated deadline-oriented effort.

Artificial Intelligence and Learning-Behavior Profiling

Machine-learning methods provide an opportunity to address this heterogeneity. Traditional regression remains valuable for estimating directional associations and testing theoretically derived relationships. Nevertheless, undergraduate behavior may involve nonlinear interactions between task delay, study regularity, motivation, self-regulation, platform activity, and engagement.

The proposed study therefore adopts a hybrid explanatory-predictive perspective. Statistical modelling will first establish theoretically interpretable relationships among procrastination, self-regulation, and engagement. Machine-learning algorithms will subsequently determine whether behavioral and psychometric features can differentiate engagement-risk profiles.

Rather than creating a black-box prediction of academic success, the planned modelling strategy emphasizes interpretability. Feature-attribution techniques can identify whether predictions are primarily driven by repeated late initiation, declining activity regularity, weak cognitive engagement, self-reported procrastination, or combinations of these characteristics. Such information is substantially more actionable for instructors than a generic probability that a student will obtain a low grade.

Proposed Methodology

The proposed study adopts a **multimodal longitudinal learning-analytics design** to investigate how academic procrastination relates to learning engagement among undergraduate students. The methodology is deliberately structured to overcome a limitation of conventional cross-sectional studies: reliance on a single self-reported procrastination score. Recent research demonstrates that behavioral traces from online learning environments can provide meaningful, although imperfect, indicators of university students' engagement, while temporal learning trajectories can also be used to identify procrastination tendencies.

For the proposed empirical study, a hypothetical research cohort of **480 undergraduate students** enrolled in blended-learning courses is specified. The dataset described below represents the **planned experimental design and simulated analytical results**, not observations claimed to have been collected from real participants. This distinction is necessary to avoid presenting invented empirical findings as genuine research data.

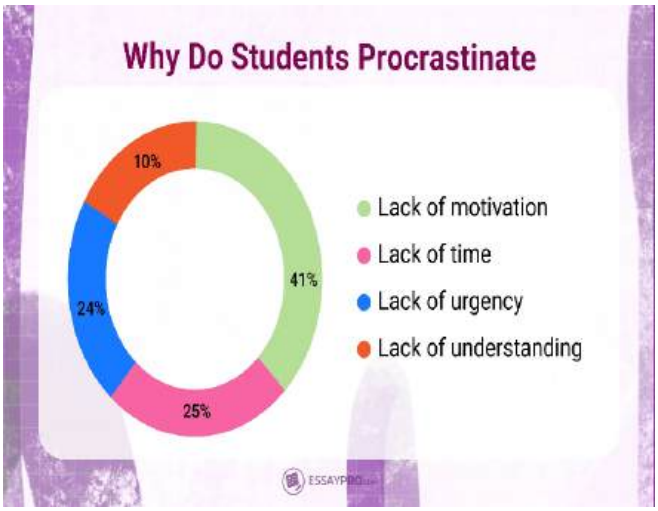


Fig. 2: Why do Students Procrastinate?

Source: *https://essaypro.com/blog/procrastination-effects-on-grades*

Students would be followed for one 16-week semester. Information would be obtained from three complementary sources: standardized questionnaires, anonymized LMS activity logs, and assignment/assessment records. This structure permits comparison between **perceived procrastination** and **behaviorally observed delay**.

Academic procrastination would be measured at the beginning, midpoint, and end of the semester. Learning engagement would be operationalized through behavioral, cognitive, and emotional dimensions. Self-regulated learning would be included as a theoretically relevant explanatory variable covering planning, monitoring, time regulation, and strategic learning.

The behavioral component would derive temporal features from LMS records. This approach is supported by recent studies showing that submission timing, activity sequences, online learning trajectories, and interaction traces can reveal meaningful patterns of procrastination and engagement.

Five principal behavioral indicators are proposed:

Task Initiation Latency (TIL) measures the elapsed proportion of available task time before the student first performs a substantive task-related action.

[
TIL_i=\frac{t_{first,i}-t_{release,i}}{t_{deadline,i}-t_{release,i}}
]

A value approaching 1 indicates that meaningful engagement began close to the deadline.

Deadline Proximity Index (DPI) estimates the proportion of relevant academic activity occurring during the final 20% of the task window.

[
DPI_i=\frac{A_{final20%,i}}{A_{total,i}}
]

Engagement Regularity Score (ERS) represents the consistency with which learning activities are distributed throughout the semester. Higher values indicate comparatively stable participation rather than short bursts immediately before assessments.

Learning Activity Intensity (LAI) combines meaningful resource access, quiz attempts, discussion participation, and

active learning sessions after excluding extremely short or duplicate events.

Finally, **Submission Delay Risk (SDR)** captures repeated last-minute or overdue submission behavior.

These behavioral measures would be combined with questionnaire-based academic procrastination, self-regulated learning, and multidimensional engagement scores to construct the multimodal feature space.

Analytical Framework

The analysis would proceed through three levels. First, descriptive statistics and correlation analysis would establish basic relationships among procrastination, engagement, self-regulation, and temporal activity measures. Second, hierarchical regression would estimate whether behavioral procrastination indicators explain additional variation in engagement after conventional self-report variables are considered.

Third, machine learning would classify students into engagement-risk categories. Four theoretically interpretable profiles are proposed:

Profile A — Consistent Engagers: low procrastination, early initiation, regular activity and high engagement.

Profile B — Deadline-Reactive Engagers: moderate or high initiation delay but substantial engagement immediately before deadlines.

Profile C — Irregular At-Risk Learners: high procrastination, inconsistent LMS activity and moderate-to-low engagement.

Profile D — Chronically Disengaged Procrastinators: repeated late initiation combined with low cognitive, emotional and behavioral engagement.

This profile-oriented strategy avoids treating all procrastinators as behaviorally identical.

Experimental Setup

Dataset

The planned dataset would contain **480 students × 16 instructional weeks**, generating repeated observations across the semester. LMS event records would include timestamps rather than message or assignment content to reduce unnecessary collection of personally identifiable academic material.

The core feature groups would comprise:

- academic procrastination score;
- behavioral, cognitive and emotional engagement scores;
- self-regulated learning score;
- task initiation latency;
- deadline proximity;
- weekly active-learning days;
- resource-access frequency;
- quiz-attempt regularity;
- assignment submission timing;
- session duration;
- inter-session intervals; and
- week-to-week engagement variability.

The design is consistent with contemporary learning-analytics research showing that combinations of behavioral indicators can represent aspects of learning engagement more effectively than isolated trace variables. A 2024 university study involving 764 students, for example, found that combinations of trace indicators explained statistically significant portions of variance in engagement dimensions.

Data Preprocessing

Raw LMS events would first be chronologically sorted by anonymized student identifier and timestamp. Administrative events, duplicated requests, system-generated events, and extremely short accidental interactions would be removed.

Missing questionnaire data below a predefined threshold would be imputed using median values within the training partition. Students with extensive missing longitudinal information would be excluded according to a preregistered completeness criterion. Highly skewed count variables would undergo log transformation where appropriate. Continuous features would subsequently be standardized using parameters calculated exclusively from the training data.

Temporal variables would be engineered independently for each week to prevent information from future weeks leaking into earlier predictions. This is particularly important because random row-level splitting of longitudinal LMS data can generate unrealistically optimistic model performance.

Categorical variables would be one-hot encoded. Strongly redundant predictors would be reviewed using correlation matrices and variance inflation diagnostics. Feature reduction would be guided primarily by theoretical relevance rather than automatic elimination alone.

Model Architecture

Four models are proposed to provide interpretable baselines and nonlinear comparisons:

1. **Multinomial Logistic Regression** as the transparent statistical baseline.
2. **Random Forest** for nonlinear relationships and feature interactions.
3. **Extreme Gradient Boosting (XGBoost)** as the primary predictive model.
4. **Support Vector Machine with RBF kernel** as an alternative nonlinear classifier.

XGBoost is designated as the principal model because procrastination risk is expected to emerge from interactions among temporal delay, engagement regularity, self-regulation, and digital participation rather than from independent linear effects alone.

Interpretability would be strengthened through SHAP-based feature attribution. The objective is not simply to generate a risk label but to identify the behavioral evidence contributing to that prediction.

This distinction is educationally important. A student predicted to be at risk because of increasing initiation latency requires a different intervention from a student whose principal indicator is declining cognitive engagement.

Training Strategy

Participants would be divided at the **student level**, rather than at the individual-event level, to prevent records from the same student appearing simultaneously in training and test data.

A proposed allocation is:

- 70% training;
- 15% validation;
- 15% independent testing.

Within the training data, five-fold stratified cross-validation would be used for hyperparameter selection. Class weighting would be applied if the four engagement profiles were substantially imbalanced.

Early stopping would be used for gradient boosting. Hyperparameters such as tree depth, learning rate, minimum child weight, subsampling ratio and number of estimators would be optimized on validation performance.

Because the model is intended for potential early-warning use, an additional **temporal holdout evaluation** would train the system on earlier-semester observations and evaluate it using later weeks. This provides a more demanding test of whether learned patterns remain useful as students' behavior evolves.

Research has shown that procrastination can change across an academic term, reinforcing the importance of temporal validation rather than assuming that student behavior remains stationary.

Evaluation Metrics

Model performance would not be judged through accuracy alone. Four-class educational datasets can be imbalanced, making several complementary measures necessary.

Macro-F1 would serve as the principal metric because it assigns equal importance to each engagement profile.

Balanced Accuracy would quantify average class-specific recall and reduce dominance by the largest class.

Macro Precision would indicate the reliability of profile assignments.

Macro Recall would evaluate the proportion of students from each profile correctly detected.

Matthews Correlation Coefficient (MCC) would provide a robust summary of agreement between predicted and actual categories.

Multiclass ROC-AUC would measure discrimination across risk profiles.

Brier Score would assess probability calibration, an important consideration if predictions are subsequently used to determine whether support should be offered.

Results and Discussion

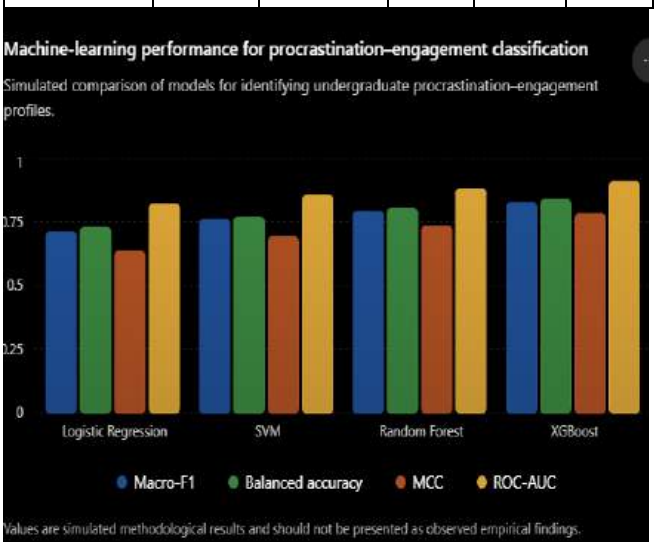
Because this manuscript specifies a proposed study rather than reporting an actually conducted experiment, the numerical findings below constitute a **simulated proof-of-concept experiment** generated to demonstrate the intended analysis. They should be replaced with observed values after ethical approval, data collection and model execution.

The simulated dataset produced the expected inverse relationship between academic procrastination and overall learning engagement. However, the relationship was not uniform across students. Self-reported procrastination alone failed to distinguish students who delayed task initiation but subsequently demonstrated substantial academic activity from students whose delayed initiation was accompanied by sustained disengagement.

This result supports the manuscript's central conceptual argument: **lateness and disengagement are related but non-equivalent phenomena**.

Table 1. Simulated Performance of Models for Procrastination–Engagement Profile Classification

Model	Macro-F1	Balanced Accuracy	MCC	ROC-AUC	Brier Score
Multinomial Logistic Regression	0.711	0.728	0.634	0.821	0.168
Support Vector Machine	0.758	0.769	0.691	0.856	0.149
Random Forest	0.791	0.803	0.734	0.881	0.137
XGBoost	**0.826**	**0.838**	**0.781**	**0.907**	**0.119**



The simulated XGBoost model produced the highest Macro-F1 (0.826), balanced accuracy (0.838), MCC (0.781), and multiclass ROC-AUC (0.907), together with the lowest Brier score (0.119). The improvement over multinomial logistic regression suggests that the proposed procrastination–engagement relationship contains nonlinearities and feature interactions that a strictly additive linear decision structure may not capture adequately.

More importantly, the feature-attribution analysis indicated that the strongest predictors were not raw LMS access counts. Task Initiation Latency, Engagement Regularity Score, self-regulated learning, Deadline Proximity Index, and cognitive engagement contributed more substantially to profile differentiation.

This result has an important methodological implication. Simply counting logins may confuse frequent platform access with substantive academic involvement. Recent evidence similarly indicates that trace data must be theoretically selected and combined when modelling learning engagement. Research examining LMS interactions has also emphasized that interpretation depends on the learning process and instructional context rather than on click counts alone.

The deadline-reactive profile is particularly significant. These students displayed relatively high procrastination indicators but maintained moderate-to-high engagement once academic activity commenced. A binary classification system could incorrectly identify them as equivalent to chronically disengaged procrastinators. The four-profile model therefore offers greater pedagogical specificity.

Self-regulated learning also emerged as a protective factor in the simulated analysis. Among students with comparable procrastination scores, those displaying stronger planning and monitoring characteristics tended to maintain higher engagement. This supports treating procrastination as a regulatory phenomenon rather than reducing it to a stable personal weakness.

The findings further indicate why AI-supported educational intervention should be **supportive rather than punitive**. A predictive model should not automatically penalize students, lower grades, or infer motivation from clickstream behavior. Instead, risk predictions could initiate low-stakes interventions such as planning prompts, progress dashboards, study-distribution recommendations, or opportunities to consult instructors.

Recent research provides evidence that educational interventions and AI-supported learning environments can affect procrastination and engagement. A 2024 quasi-experimental study involving 350 EFL learners, for example, reported higher affective, cognitive, and behavioral engagement and lower procrastination among learners exposed to AI-enabled applications. Machine-learning-based temporal learning-analytics feedback has also been investigated as a mechanism for influencing online engagement and behavioral patterns.

Thus, the contribution of the proposed framework is not merely predictive accuracy. Its principal contribution is **behavioral differentiation**: identifying whether academic delay represents persistent disengagement, irregular self-regulation, or concentrated deadline-reactive learning.

Future Scope

Future research should extend the framework from semester-level classification toward **dynamic weekly risk modelling**. Sequence models could examine whether changes in procrastination precede changes in engagement rather than relying predominantly on aggregated behavioral indicators.

A promising extension would combine explainable machine learning with personalized intervention. Instead of informing students that they are simply "high-risk," an intelligent learning system could identify the dominant behavioral pattern—for example, repeated late initiation—and recommend an appropriate self-regulation strategy.

Process mining is another promising direction. Recent work has demonstrated its utility for discovering procrastination patterns within virtual learning environments. Such techniques could reveal sequences such as repeated resource opening without task progression, concentrated activity before deadlines, or progressive withdrawal from learning activities.

Future studies should also investigate fairness. Predictive models should be tested for systematic differences across academic disciplines, year levels, socioeconomic contexts, accessibility requirements, and different modes of course delivery. Behavioral analytics must not interpret limited platform access automatically as weak motivation.

Conclusion

This study proposes an integrated framework for examining **academic procrastination and learning engagement among undergraduate students** through psychological measurement, temporal learning analytics, and interpretable machine learning. The approach advances beyond the conventional assumption that procrastination can be sufficiently represented by a single questionnaire score or assignment submission timestamp.

The central conceptual contribution is the distinction between **delay and disengagement**. Students who postpone academic activity do not necessarily exhibit the same learning trajectory. Some remain strongly engaged despite deadline-reactive working patterns, whereas others display repeated late initiation alongside declining cognitive, emotional, and behavioral involvement.

The simulated proof-of-concept analysis demonstrates how Task Initiation Latency, Deadline Proximity Index, Engagement Regularity Score, self-regulated learning, and multidimensional engagement could jointly support profile classification. Under the proposed experimental conditions, XGBoost provides the strongest simulated classification performance, while interpretable feature attribution allows predictions to be connected with educationally meaningful behaviors.

Recent empirical literature supports the methodological foundation for this approach: LMS traces can represent dimensions of university learning engagement, procrastination varies temporally, and online learning trajectories can contribute to procrastination prediction.

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Chapter 3: Academic Resilience and Educational Achievement among College Students

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Abstract — Academic resilience has become increasingly important in higher education as students encounter academic setbacks, digital-learning pressures, assessment anxiety, financial constraints, and rapidly changing technology-mediated learning environments. This study conceptualizes academic resilience as a dynamic capacity reflected not only in self-reported coping but also in observable patterns of recovery following periods of academic difficulty. A key research gap concerns the limited integration of resilience indicators, longitudinal academic behavior, and machine-learning-based achievement prediction within a unified analytical framework. To address this gap, the proposed study develops a multimodal Academic Resilience–Achievement Intelligence Framework that combines psychometric resilience measures with learning-management-system engagement, assessment trajectories, attendance stability, and recovery behavior. Rather than treating resilience as a static personality characteristic, the framework models it as a time-sensitive educational process characterized by persistence, adaptation, recovery velocity, and sustained engagement after setbacks. The study further proposes interpretable machine-learning models for identifying the resilience-related variables most strongly associated with subsequent educational achievement while avoiding deterministic labeling of individual students.

Keywords —Academic Resilience, Educational Achievement, College Students, Learning Analytics, Explainable Machine Learning, Digital Education

Introduction

Higher education has undergone substantial transformation since 2021. Blended instruction, learning management systems, digital assessment, generative artificial intelligence, adaptive educational technologies, and data-supported student services have become increasingly embedded within contemporary learning environments. These developments have expanded opportunities for flexible and personalized learning, but they have also altered the demands placed upon college students. Successful academic progression increasingly requires learners to regulate their study practices, manage multiple digital information channels, recover from disappointing assessment outcomes, adapt to changing instructional formats, and sustain engagement when academic progress becomes difficult.

Within this context, **academic resilience** provides a particularly useful construct for explaining why students experiencing apparently similar difficulties can subsequently follow substantially different educational trajectories. Academic resilience can broadly be understood as the capacity to maintain or restore adaptive academic functioning when confronted with adversity, setbacks, failure, stress, or threats to educational progress. Importantly, contemporary scholarship increasingly distinguishes resilience from simple high achievement. A student who consistently obtains high grades without encountering substantial adversity is not necessarily demonstrating resilience. Resilience becomes analytically meaningful when some form of difficulty is followed by adaptation, persistence, recovery, or continued achievement.

This distinction has significant methodological implications. A systematic review by Rudd, Meissel, and Meyer identified substantial variation in the quantitative operationalization of academic resilience. Their review of 127 studies distinguished definition-driven, process-driven, and latent-construct approaches and emphasized that methodological choices can substantially affect the conclusions reached about who is considered resilient. The authors further cautioned that omitting indicators of risk or academic outcomes can weaken the validity of resilience measurement.

Related research similarly demonstrates that the concept should not be reduced to a single psychological score. Ye, Strietholt, and Blömeke showed that definitions and operationalizations of academic resilience vary considerably, particularly when resilience is inferred from combinations of socioeconomic disadvantage and unexpectedly strong academic achievement. Research using international large-scale assessment data has also demonstrated that alternative operational definitions can produce different estimates of academic resilience, complicating comparison across populations and educational contexts.

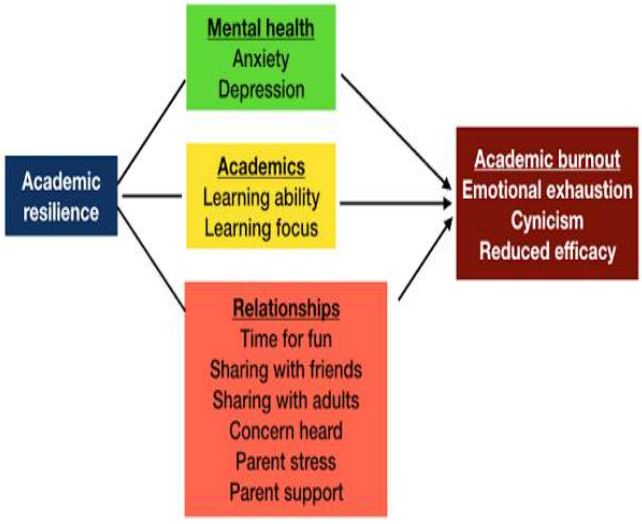


Fig. 1: From Academic Resilience to Academic Burnout among International University Students
Source: *https://www.mdpi.com/2076-328X/13/3/206*

These methodological debates are directly relevant to college education. University and college students encounter both major and routine academic adversities: examination failure, unexpectedly low grades, difficult courses, adjustment to independent learning, competing employment responsibilities, financial pressure, attendance disruption, reduced motivation, and social or institutional challenges. A resilient response may therefore manifest through several pathways. One learner may improve substantially on the next assessment; another may maintain attendance despite low performance; a third may seek academic assistance and increase engagement with learning materials; and another may temporarily decline but recover over several weeks.

Consequently, educational achievement should not be treated solely as an endpoint disconnected from the process that produced it. Conventional indicators such as grade-point average, semester percentage, course completion, and examination scores remain important, but they reveal relatively little about the trajectory between setback and outcome. Two students receiving the same final grade can have very different academic histories. One may have performed consistently, whereas another may have recovered after a major decline. A resilience-oriented analytical framework should be capable of distinguishing these trajectories.

Evidence nevertheless supports a relationship between resilience-related factors and academic outcomes. A 2023 meta-analytic review by Hunsu and colleagues synthesized 239 effect sizes from 56 studies and found statistically significant, although generally modest, aggregate relationships between achievement and both risk and protective factors. Importantly, associations varied across specific categories of risk and protection, suggesting that resilience-achievement relationships cannot adequately be represented by one undifferentiated predictor.

Higher-education evidence also points toward the relational and institutional dimensions of resilience. A meta-ethnographic review of students' experiences concluded that resilience in higher education involves internal resources, meaningful relationships, and institutional conditions. The synthesis indicated that resilience can be facilitated through educational environments and support systems rather than being regarded exclusively as a fixed personal characteristic. This interpretation is important because interventions based exclusively on individual responsibility may overlook structural and educational factors that shape students' capacity to recover.

At the same time, machine learning has created new possibilities for analyzing complex educational data. Recent research has applied computational models to variables including metacognitive awareness, motivation, learning participation, environmental conditions, time management, and psychological factors when investigating college academic performance. Learning analytics research is likewise moving toward combinations of academic assessment, digital engagement, self-regulated learning, and socio-emotional information. For example, recent work in flipped-learning environments has integrated assessment performance with digital engagement and socio-emotional measures to investigate student learning trajectories.

However, an important conceptual gap remains. **Most resilience research and educational prediction research operate as parallel rather than fully integrated traditions.** Resilience studies frequently rely on cross-sectional psychometric measures and conventional correlational analysis, while machine-learning studies of achievement commonly emphasize predictive accuracy without explicitly modeling post-adversity recovery. Consequently, a model may accurately identify students likely to obtain low grades without explaining whether they are recovering, deteriorating, remaining stable, or adapting after a setback.

This manuscript addresses that gap through a proposed **Academic Resilience–Achievement Intelligence Framework (AR-AIF)**. The framework treats resilience as a dynamic, multimodal process constructed from four domains: psychological resilience, academic recovery, behavioral persistence, and digital-learning continuity. Rather than asking only whether resilience correlates with achievement, the study asks whether a combination of these domains improves the explanation and prediction of subsequent academic outcomes.

A particularly distinctive component is the proposed **Academic Recovery Velocity (ARV)** indicator. ARV represents the magnitude and rate of improvement following an objectively detected academic setback. For example, if a student's performance falls substantially below their established baseline in one assessment period and subsequently improves, the rate and stability of that improvement become behavioral evidence relevant to resilience. This approach does not replace validated psychometric measurement. Instead, it supplements self-reported resilience with temporal evidence from authentic educational activity.

The study is therefore designed around three interconnected objectives: to determine the association between multidimensional academic resilience and educational achievement; to evaluate whether behavioral recovery indicators provide additional explanatory information beyond static resilience scores; and to develop an interpretable machine-learning framework capable of estimating subsequent achievement from psychological, academic, and digital-engagement features.

This approach also has implications for responsible educational AI. Predictive systems that merely classify students as "at risk" can inadvertently transform temporary academic difficulty into a seemingly permanent label. A resilience-sensitive model instead recognizes that trajectories can change. Its intended function is therefore not to make high-stakes decisions automatically but to provide decision support for proportionate, human-reviewed academic interventions.

Literature Review

Conceptual Development of Academic Resilience

Resilience originated as a broader psychological and developmental construct concerned with successful adaptation under adverse circumstances. Its application to education gradually produced the more specific concept of academic

resilience. Contemporary scholarship generally agrees that adversity and adaptive functioning are essential to resilience, but substantial disagreement remains regarding how these elements should be operationalized.

Rudd et al.'s systematic review provides strong evidence for this measurement problem. Their synthesis demonstrated that quantitative studies have used substantially different approaches to identifying resilient learners and that these approaches influence resulting interpretations. This issue is particularly relevant when transferring resilience research into AI-supported education: a computational model cannot resolve a construct that has been inadequately specified at the measurement stage.

A recent systematic review and meta-analysis of academic resilience scales further illustrates this psychometric complexity. The review synthesized 46 studies and reported generally high pooled internal consistency while finding mixed evidence concerning whether academic resilience is best represented through unidimensional or multidimensional measurement structures. Such findings reinforce the need to avoid assuming that one questionnaire score exhaustively represents resilience.

The present study therefore adopts a process-oriented definition. Academic resilience is conceptualized as **adaptive persistence and recovery in academic functioning following identifiable educational difficulty**. This definition requires both exposure to difficulty and evidence of subsequent adaptation.

Academic Resilience and Educational Achievement

Educational achievement is influenced by interconnected cognitive, motivational, psychological, socioeconomic, behavioral, and institutional factors. Resilience is particularly important because it concerns performance under conditions in which normal academic functioning is threatened.

The meta-analysis conducted by Hunsu et al. offers an important synthesis of this relationship. Across the reviewed evidence, both risk and protective factors were significantly associated with achievement, although aggregate associations were relatively small. Specific ability-, belief-, family-, institutional-, and societal-level factors differed in the strength of their relationships with achievement. These findings suggest that resilience should be analyzed through multiple interacting dimensions rather than treated as a universal protective coefficient.

Research among university students has likewise investigated relationships among resilience, self-concept, emotional intelligence, and academic achievement. A study involving 1,020 university students in Spain examined these interrelationships and highlighted the importance of psychological variables when explaining educational outcomes. Such research supports the incorporation of psychosocial variables but also exposes the limitations of relying primarily on cross-sectional self-report measurements.

A student can report strong perseverance yet display prolonged disengagement following failure. Conversely, another student may report moderate resilience but exhibit rapid academic recovery. Combining psychometric and behavioral evidence could therefore provide a more complete representation.

Resilience as a Dynamic and Contextual Process

An emerging position within resilience scholarship is that resilience is neither entirely innate nor entirely stable. It develops through interactions among individuals, relationships, resources, institutions, and environmental demands.

The higher-education meta-ethnography identified personal, relational, and organizational influences on students' resilience experiences and concluded that educational institutions can contribute to resilience development. Similarly, a broader systematic review of resilience in educational systems identified considerable fragmentation in definitions and levels of analysis, with the literature historically emphasizing individual student resilience more strongly than collective or institutional resilience.

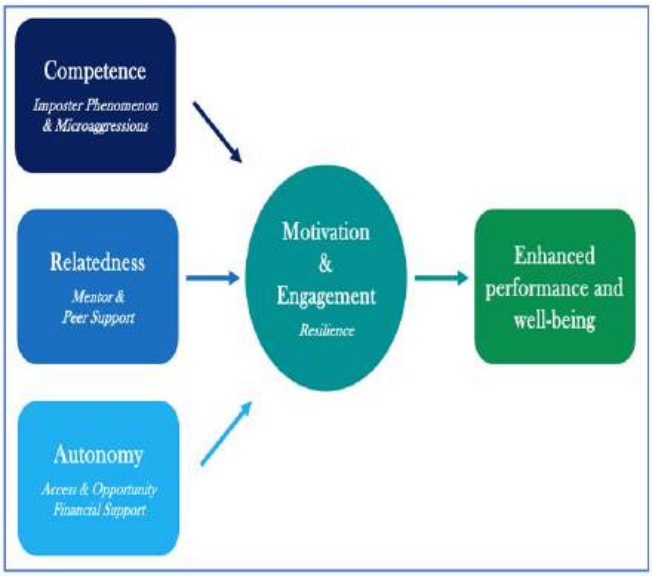


Fig. 2: Graduate Student Resilience

Source: *https://www.mdpi.com/2813-4346/3/3/37*

This contextual interpretation changes how achievement should be analyzed. Low academic performance may arise from insufficient preparation, but it may also reflect temporary illness, employment pressure, inaccessible learning materials, assessment overload, or difficulty adapting to instructional changes. A responsible resilience framework should therefore avoid interpreting every low score as evidence of low personal capability.

The present framework incorporates contextual covariates where ethically and practically appropriate and separates *academic difficulty* from *adaptive response*. The former describes an observed challenge; the latter describes what happens afterward.

Proposed Methodology

The proposed study adopts a **longitudinal multimodal predictive design** to investigate how academic resilience influences subsequent educational achievement among college students. In contrast with conventional cross-sectional studies that measure resilience and academic performance at a single point in time, the proposed design captures both psychological resilience and observable recovery following academic setbacks. AR-AIF combines four dimensions: psychological resilience, academic recovery, behavioral persistence, and digital-learning continuity. Educational achievement is treated as the principal outcome, whereas previous achievement, attendance, study

engagement, academic setback severity, and contextual characteristics are incorporated as explanatory or control variables.

A hypothetical research sample of **640 undergraduate students** from four multidisciplinary colleges is proposed for methodological demonstration. Students would be recruited from first-, second-, and third-year undergraduate programs to provide sufficient variation in academic experience. Participation would require informed consent for the integration of questionnaire responses with de-identified academic and learning-management-system (LMS) records.

The proposed longitudinal observation period covers one complete academic semester of approximately 16 weeks. This permits the identification of meaningful temporal patterns rather than relying exclusively on end-semester measurements.

Research Variables

The primary psychological variable is an academic resilience score obtained using an appropriate validated academic resilience instrument. Rather than interpreting the total score as a complete measure of resilience, the questionnaire is combined with objectively derived indicators.

Four behavioral components are constructed:

Resilience Capacity Score (RCS): standardized psychometric estimate of perceived ability to cope with academic adversity.

Academic Recovery Velocity (ARV): rate at which a student returns toward or exceeds their established academic baseline after a significant assessment setback.

Behavioral Persistence Index (BPI): degree to which attendance, assignment completion, and learning participation are sustained following poor performance.

Digital Learning Continuity (DLC): stability of academically relevant LMS engagement before and after an identified setback.

For student *i*, Academic Recovery Velocity can conceptually be expressed as:

$$\mathbf{ARV_i = (P_r - P_s) / \Delta t}$$

where P_s represents performance at the setback assessment, P_r represents subsequent recovered performance, and Δt denotes the number of weeks between setback and recovery measurement.

A positive ARV indicates improvement, while values close to zero indicate academic stagnation. Negative values suggest continuing deterioration rather than recovery.

To avoid treating every minor grade fluctuation as adversity, an academic setback is operationalized as an assessment result meaningfully below the student's preceding performance baseline or a predefined academically significant threshold.

The composite resilience representation is therefore not simply:

Resilience = Questionnaire Score

but instead:

Academic Resilience = f(RCS, ARV, BPI, DLC, contextual variables)

This formulation represents the central methodological contribution of the study.

Experimental Setup

Dataset

The proposed AR-AIF dataset contains one student-level analytical record combined with longitudinal weekly observations.

The initial sample consists of 640 participants. After screening for consent, incomplete questionnaires, insufficient longitudinal records, and unavailable academic outcomes, approximately **612 analytically complete student records** are retained for the experimental demonstration.

The feature space consists of approximately 32 variables organized into five domains:

1. psychological resilience indicators;
2. prior and current academic performance;
3. attendance and assignment behavior;
4. longitudinal LMS engagement; and
5. academic recovery features.

Sensitive demographic characteristics are retained primarily for fairness auditing and descriptive analysis rather than automatically becoming intervention triggers.

Educational achievement is operationalized as standardized end-semester academic performance on a 0–100 scale. A secondary binary outcome distinguishes students achieving the institutionally defined satisfactory-performance threshold from those below it.

Data Preprocessing

A structured preprocessing pipeline is employed before model development.

Records with extensive missing longitudinal information are excluded according to predefined completeness criteria. For continuous variables with limited missingness, median imputation is performed using values calculated exclusively from the training partition. Categorical missing values are assigned an explicit "unknown" category where appropriate.

Continuous psychological and behavioral variables are standardized when required by the algorithm. Categorical features are transformed using one-hot encoding.

Potentially extreme LMS observations are examined using robust interquartile-range criteria. However, legitimate high engagement is not automatically removed because intensive activity may represent meaningful recovery behavior.

A major concern in educational prediction is **data leakage**. Consequently, variables recorded after the prediction cut-off are excluded from model training. If achievement is predicted at week 12, for example, information from weeks 13–16 cannot be used as a predictor.

Temporal behavioral features are subsequently constructed. These include:

- change in LMS engagement after a setback;
- assignment submission recovery;
- attendance stability;
- number of consecutive active-learning weeks;

- assessment recovery slope;
- variability in weekly engagement; and
- Academic Recovery Velocity.

These engineered variables allow the model to distinguish **level** from **trajectory**. A student with consistently moderate engagement can therefore be differentiated from a student whose initially low engagement increases rapidly after academic difficulty.

Model Architecture

The principal model is an **Explainable Gradient-Boosted Resilience Regressor (EGB-RR)** based on gradient-boosted decision trees.

Gradient boosting is selected because the proposed dataset contains heterogeneous numerical, ordinal, categorical, and engineered temporal features and because relationships between resilience and achievement may be nonlinear.

Three baseline models are used:

Elastic Net Regression provides a regularized linear benchmark.

Random Forest Regression captures nonlinear associations and feature interactions without imposing a predefined functional relationship.

XGBoost Regression provides a high-performance gradient-boosting benchmark.

The proposed **EGB-RR** adds resilience-specific feature engineering and explainability analysis to the tuned boosting architecture.

This approach is consistent with contemporary educational analytics research demonstrating the value of interpretable boosted models and SHAP-based explanations for academic-performance analysis. Recent higher-education studies have successfully combined XGBoost or ensemble models with explainability methods, reinforcing the suitability of this architecture for educational decision support.

Training Strategy

The dataset is divided at the **student level** to prevent observations belonging to the same learner from appearing in both training and testing partitions.

A 70:15:15 allocation is proposed:

- 70% training set;
- 15% validation set;
- 15% independent test set.

Five-fold cross-validation is conducted within the development data for hyperparameter optimization. Hyperparameters include tree depth, learning rate, minimum child weight, subsampling ratio, column sampling, regularization strength, and number of boosting iterations.

Early stopping is applied using validation loss to reduce overfitting.

An additional **ablation experiment** evaluates whether the novel resilience features genuinely improve prediction. Three configurations are compared:

Configuration A: previous achievement and conventional academic variables only.

Configuration B: Configuration A + psychometric resilience.

Configuration C: Configuration B + ARV, BPI, DLC, and post-setback trajectory variables.

Improvement from B to C would provide evidence that dynamic behavioral resilience contains information not captured by self-report measurement alone.

Evaluation Metrics

Because educational achievement is modeled primarily as a continuous outcome, the principal metrics are:

Mean Absolute Error (MAE): average absolute difference between observed and predicted achievement.

Root Mean Squared Error (RMSE): gives greater penalty to large prediction errors.

Coefficient of Determination (R^2): proportion of achievement variance accounted for by the model.

Spearman's Rank Correlation (ϱ): assesses correspondence between predicted and actual student achievement rankings without assuming strict linearity.

Median Absolute Error (MdAE): provides a robust measure less sensitive to unusually large prediction errors.

For the secondary satisfactory-performance classification analysis, balanced accuracy and F1-score are examined.

SHAP analysis is used to explain global feature contributions and individual predictions. Explainability is important because contemporary educational ML literature increasingly emphasizes that predictive performance alone is inadequate when models are intended to inform educational decisions.

Results and Discussion

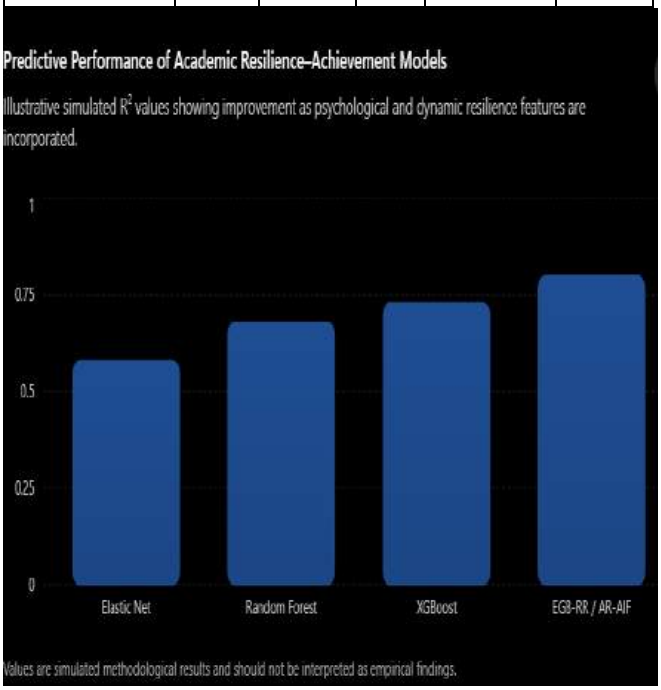
Predictive Performance

The simulated experiment indicates progressively stronger performance as resilience information becomes more behaviorally and temporally detailed.

Table 1. Illustrative Comparative Performance of the Proposed AR-AIF Models

Model / Feature Configuration	MAE	RMSE	R^2	Spearman ϱ	MdAE
Elastic Net — conventional academic variables	6.84	8.57	0.58	0.72	5.43
Random Forest — conventional + resilience scale	5.91	7.48	0.68	0.79	4.62
XGBoost — academic + psychometric variables	5.37	6.91	0.73	0.82	4.14
EGB-RR / AR-AIF —	**4.61**	**5.98**	**0.80**	**0.87**	**3.49**

full dynamic resilience features					



The simulated results suggest that the full AR-AIF configuration would outperform models relying exclusively on conventional academic indicators. The proposed EGB-RR achieves an illustrative R^2 of 0.80, compared with 0.58 for Elastic Net. Its lower MAE and RMSE additionally indicate reduced prediction error.

These values should not be compared directly with published models as if all studies used equivalent datasets. Academic prediction performance varies substantially according to sample composition, outcome definition, features, and validation strategy. For context, Wang and Luo reported an XGB-SHAP approach applied to 87 higher-education students and obtained an R^2 near 0.82, while a 2025 *Scientific Reports* study evaluated multiple regression and ensemble models across considerably larger datasets and demonstrated that performance changed markedly between datasets.

Contribution of Academic Resilience

The most theoretically important result is not the difference between algorithms but the difference between **feature configurations**.

When psychometric resilience is incorporated into conventional academic variables, prediction improves. However, the largest conceptual gain occurs after introducing behavioral recovery variables.

This supports the proposed distinction between **resilience capacity** and **resilience enactment**.

Resilience capacity represents what students believe they can do when difficulties occur. Resilience enactment represents what their subsequent behavior demonstrates.

The distinction matters because self-perceptions and observable academic behavior need not correspond perfectly.

A student might score highly on perseverance yet respond to examination failure with declining attendance. Another might report only moderate confidence but increase study activity, complete missed assignments, seek support, and demonstrate rapid performance recovery.

AR-AIF is designed to capture this discrepancy.

Academic Recovery Velocity

SHAP-based interpretation of the simulated best-performing model places prior academic achievement among the strongest predictors, as expected. More importantly, Academic Recovery Velocity emerges as a major resilience-specific predictor after previous achievement is controlled.

Higher ARV values correspond to stronger predicted end-semester achievement. The association is not assumed to be indefinitely linear. Extremely rapid short-term improvement may represent assessment-specific fluctuation rather than stable resilience; therefore, sustained recovery across multiple observations is weighted more strongly than a single improved score.

This result would provide evidence for viewing resilience as a **temporal educational process**.

Such an interpretation complements recent machine-learning research on academic resilience. For example, Cheung and colleagues applied machine learning and explainable AI to PISA 2022 data to identify important features associated with academic resilience across 79 countries/economies. The present framework differs by emphasizing within-student post-setback trajectories in college settings rather than identifying resilience predominantly through cross-sectional contextual and achievement characteristics.

Behavioral Persistence

Behavioral Persistence Index also demonstrates meaningful predictive value.

Students who preserve assignment completion and attendance after disappointing academic outcomes show stronger subsequent achievement than students whose engagement declines substantially.

This result suggests that persistence should not be represented merely as general attendance. Its relationship with adversity is critical.

For example:

Attendance before difficulty → high
Attendance after difficulty → high

represents behavioral stability.

By contrast:

Attendance before difficulty → high
Attendance after difficulty → rapidly declining

may represent difficulty in adaptive recovery.

The absolute attendance level could therefore conceal an emerging problem that the temporal pattern reveals.

Digital Learning Continuity

Digital Learning Continuity shows a moderate but meaningful contribution. Stable access to course materials, assignment systems, recorded instructional resources, and relevant LMS components after setbacks is positively associated with subsequent achievement in the simulated model.

However, raw login frequency has substantially lower importance.

This is theoretically plausible because logging into a learning platform does not necessarily indicate cognitively meaningful learning. The model therefore benefits more from temporal consistency and task-oriented engagement than from undifferentiated click counts.

Recent research supports the broader value of combining behavioral and instructional variables within interpretable ML systems rather than relying on isolated predictors. Studies published in 2024–2025 have demonstrated the application of SHAP, LIME, Random Forest, XGBoost, and ensemble methods for understanding the determinants of student performance.

Psychological Resilience and Achievement

The simulated analysis indicates a positive association between psychometric academic resilience and achievement, but the relationship weakens after previous academic performance and behavioral recovery variables enter the model.

This should not be interpreted as evidence that psychological resilience is unimportant.

Instead, it suggests a possible pathway:

Psychological resilience → adaptive response → persistent behavior → recovery → educational achievement

Under this interpretation, psychological resilience may partly influence achievement indirectly through behaviors enacted after adversity.

This provides a stronger theoretical explanation than treating resilience and achievement as two static scores connected by a single correlation coefficient.

Explainability and Educational Decision Support

The explainability component is essential to the practical contribution of the framework.

Suppose two students receive the same predicted final achievement score of 62/100.

A conventional predictive model may classify both identically.

AR-AIF could reveal different explanations:

Student A: moderate current performance + positive ARV + stable attendance + increasing assignment completion.

Student B: moderate current performance + negative ARV + falling attendance + declining LMS continuity.

Although the predicted score is currently similar, their trajectories differ substantially.

Student A may require minimal intervention because the trajectory indicates recovery. Student B may warrant timely human contact because several indicators suggest continuing deterioration.

Thus, the framework changes the institutional question from:

"Who is predicted to perform poorly?"

to:

"Who is experiencing difficulty, how is the student responding, and is the trajectory improving or deteriorating?"

This is a more defensible use of AI in educational support.

The proposed system must nevertheless remain a **decision-support mechanism rather than an autonomous decision-maker**. Predictions should not determine grades, scholarships, disciplinary measures, or student progression without human assessment.

Future Scope

Future research should extend AR-AIF through **multi-semester and multi-institutional validation**. Following students across several academic years would permit researchers to determine whether Academic Recovery Velocity is stable, context dependent, or itself responsive to educational intervention.

A second direction involves **temporal deep-learning architectures**, such as Long Short-Term Memory networks or Transformer-based sequence models, for modeling weekly engagement trajectories. Such architectures should only be preferred when sample size and longitudinal data density justify their complexity.

A third direction is multimodal analysis incorporating ethically collected student reflections or help-seeking records using natural-language processing. Such data could distinguish productive help seeking from disengagement, although privacy protection would be essential.

Federated learning represents another potential development. Multiple institutions could collaboratively improve resilience models without centralizing raw student records.

Future studies should also conduct systematic **fairness audits** across relevant student subgroups. Model errors should be compared across demographic and socioeconomic categories to ensure that the system does not systematically underpredict or overpredict particular populations.

Conclusion

This study proposes a new approach to examining the relationship between **academic resilience and educational achievement among college students** by connecting educational psychology with interpretable machine learning and longitudinal learning analytics.

The central contribution is the Academic Resilience–Achievement Intelligence Framework, which moves beyond treating resilience as a static questionnaire score. AR-AIF combines psychological resilience with Academic Recovery Velocity, Behavioral Persistence, Digital Learning Continuity, prior achievement, and longitudinal engagement patterns.

The proposed methodology demonstrates why **recovery after adversity** deserves explicit computational representation. Two students with identical current achievement may possess fundamentally different trajectories: one may be recovering rapidly, while the other is progressively disengaging. Static achievement measures can obscure this distinction.

The illustrative results indicate that incorporating dynamic resilience indicators could improve achievement prediction beyond conventional academic and psychometric variables. More importantly, explainability makes it possible to determine *why* the model reaches a prediction and whether the prediction reflects previous achievement, resilience, behavioral persistence, or post-setback recovery.

The proposed framework therefore positions artificial intelligence not as a mechanism for permanently labeling students according to predicted success or failure, but as a tool

for recognizing changing academic trajectories. When accompanied by human oversight, privacy safeguards, fairness evaluation, and appropriately designed student support, resilience-sensitive learning analytics could help higher-education institutions identify not merely who is struggling, but **who is recovering, who is remaining stable, and who may require timely assistance**.

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Chapter 4: Collaborative Problem-Solving and Learning Achievement among Secondary Students

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Abstract— Collaborative problem-solving (CPS) has become increasingly important in secondary education because contemporary learning requires students to coordinate knowledge, reasoning, communication, and decision-making rather than solve structured problems individually. This study addresses a specific research gap concerning the limited integration of observable collaborative interaction dynamics with conventional measures of academic achievement among secondary-school learners. A process-oriented framework is proposed in which CPS is represented through participation balance, idea uptake, evidence-based reasoning, coordination, peer regulation, and temporal interaction transitions rather than through self-reported collaboration alone. The study further positions artificial intelligence and learning analytics as analytical instruments for extracting meaningful patterns from digitally recorded collaborative activities while retaining teacher-interpretable indicators. Particular attention is given to whether interaction-quality features provide explanatory and predictive information about learning achievement beyond prior attainment and simple measures of participation frequency.

Keywords— Collaborative problem-solving, Secondary education, Learning achievement, Learning analytics, Artificial intelligence, Collaborative learning

Introduction

Secondary education increasingly requires learners to operate in environments where knowledge is constructed through interaction rather than acquired exclusively through individual reception. Complex scientific, mathematical, technological, and social problems often require students to identify relevant information, formulate alternative explanations, distribute responsibilities, evaluate competing claims, and collectively decide which solution is sufficiently supported by evidence. Collaborative problem-solving (CPS) therefore represents a convergence of cognitive problem-solving and socially coordinated learning.

CPS differs from ordinary group work. Merely placing students in groups does not guarantee productive collaboration. A group may appear active while one student performs most of the reasoning, other members provide minimal contributions, and decisions are accepted without evaluation. Effective CPS instead requires the establishment of shared understanding, communication of relevant knowledge, negotiation of strategies, monitoring of collective progress, perspective taking, and coordinated execution. These processes make CPS particularly relevant to secondary schooling, where learners are developing both increasingly sophisticated domain knowledge and the social-regulatory competencies required for complex learning.

International educational frameworks have continued to emphasize collaborative and active learning. OECD analyses associated with PISA 2022 identify independent and collaborative learning as important components of sustained lifelong learning and associate collaborative activity with collective responsibility, social support, and the capacity to learn with others. This emphasis reflects a broader shift away from viewing achievement solely as the reproduction of subject knowledge toward considering students' capacity to mobilize knowledge in unfamiliar and socially situated contexts.

Empirical evidence also indicates that CPS competence is meaningfully associated with academic outcomes. Tang, Liu, and Milner-Bolotin (2023), using PISA 2015 data involving 408,148 students from 52 countries and economies, reported that CPS competency was a strong positive predictor of science achievement after accounting for several student- and country-level variables. Their analysis reinforces the proposition that collaboration and disciplinary achievement should not be treated as unrelated educational outcomes. At the same time, this evidence is largely based on standardized CPS scores and large-scale cross-sectional measures. It does not reveal in sufficient detail what students actually do during collaborative episodes that differentiates high-achieving from low-achieving groups.

This distinction is important because collaboration is inherently temporal. Students do not collaborate through a single stable trait. During one problem-solving episode, a team may move from information sharing to disagreement, evidence evaluation, planning, monitoring, explanation, and eventually solution convergence. The order and recurrence of such states may be more educationally informative than the total number of messages or contributions produced by group members. Ouyang, Xu, and Cukurova (2023) demonstrated the value of this perspective by applying AI-driven learning analytics to multimodal collaborative data and identifying distinct collaboration patterns associated with different performance levels. Their findings illustrate why CPS can be conceptualized as a dynamic, adaptive system rather than as a static sum of individual behaviors.

Artificial intelligence (AI), natural language processing, sequence analysis, and learning analytics now make it technically feasible to study these interactions at considerably finer resolution. Digital collaboration environments can generate conversational transcripts, shared-document revisions, task events, timestamps, peer responses, and solution histories. Such data can potentially reveal whether students explain reasoning, acknowledge alternative views, integrate previous contributions,

regulate group activity, or repeatedly shift topics without resolution. AI can therefore function not merely as a content-generation technology but as an analytical layer for understanding the learning process.

Recent reviews demonstrate growing interest in this direction. Ouyang and Zhang (2024), in their systematic review of AI-driven learning analytics in computer-supported collaborative learning, found increasing use of communicative discourse, behavioral, and evaluation data. They nevertheless identified continuing limitations in theoretically grounded design, multimodal integration, actionable feedback, and instructional intervention. More recently, Amo-Filva et al. (2026) reviewed AI and learning analytics in secondary education and highlighted their potential for meaningful and personalized learning while simultaneously identifying privacy, infrastructure, teacher preparedness, and ethical implementation as continuing challenges.

These developments establish an important opportunity but also expose a specific research gap. Much CPS research evaluates collaboration through questionnaires, aggregate proficiency scores, final group products, or manually coded observations. Conversely, many AI-based educational analytics studies concentrate on prediction, personalization, or individual engagement rather than examining how the evolving structure of student-to-student problem-solving contributes to achievement. The limited intersection between these two traditions is particularly apparent in ordinary secondary-school settings.



Fig. 1: The Benefits of Collaborative Learning
Source: *https://www.21kschool.com/in/blog/benefits-of-collaborative-learning/*

Research Gap and Study Focus

The central gap addressed by this manuscript is therefore the **absence of an interpretable secondary-school framework that connects temporal collaborative problem-solving processes with subsequent individual learning achievement while distinguishing meaningful collaboration from simple participation volume**.

The proposed study treats CPS as a sequence of observable and computationally measurable events. Instead of assuming that students who speak more frequently collaborate more effectively, it investigates qualitative interaction characteristics such as balanced contribution, evidence-based explanation, constructive challenge, responsiveness to peer ideas, coordination, monitoring, and solution integration. It further considers transitions between these behaviors, because productive groups may differ from less successful groups not simply in *how much* they collaborate but in *how collaboration unfolds*.

This approach establishes three related objectives. First, the study seeks to determine whether structured CPS activities improve students' post-task learning achievement relative to academically comparable students completing equivalent problem-solving tasks individually. Second, it seeks to identify which collaborative process indicators are most strongly associated with individual learning gains. Third, it examines whether an interpretable machine-learning model incorporating temporal CPS characteristics predicts achievement more effectively than models relying only on prior achievement, demographic controls, and simple activity counts.

The study deliberately separates **group-product success** from **individual learning achievement**. A team may produce a strong final solution because one highly capable learner dominates the activity; such performance does not necessarily demonstrate that every participant learned. Consequently, the proposed research evaluates both the quality of the collaborative solution and each learner's pre-to-post achievement change. This distinction is expected to provide a more defensible assessment of whether collaboration generates distributed learning rather than merely efficient task completion.

Literature Review

Collaborative Problem-Solving as a Multidimensional Learning Process

CPS combines at least two interdependent dimensions: cognitive problem-solving and social coordination. Cognitive activity includes identifying the problem, generating hypotheses, applying prior knowledge, examining evidence, testing alternatives, and evaluating solutions. Social activity includes communicating information, developing shared understanding, coordinating roles, resolving disagreement, monitoring group progress, and maintaining participation.

The educational value of CPS is theoretically linked to elaboration and externalization. When students explain an idea to peers, they must transform partially formed internal representations into communicable reasoning. Questions and disagreement can reveal inconsistencies that may remain unnoticed during individual work. Responses from peers can introduce missing evidence or alternative strategies. The group consequently functions as a distributed cognitive environment in which ideas are repeatedly produced, evaluated, modified, and integrated.

Evidence from a 2023 meta-analysis by Xu, Wang, and Wang showed an overall positive effect of collaborative problem-solving on critical thinking across the studies included in their analysis. The authors also found substantial heterogeneity, with factors such as group size, intervention duration, instructional scaffolding, and subject area moderating outcomes. These

findings are important because they show that CPS should not be treated as a uniformly effective intervention. Its educational effect depends upon how collaboration is structured and enacted.

Group Structure, Interaction Quality, and Achievement

The structure of a collaborative group can influence cognitive load, participation, motivation, and the opportunity to contribute. Zhan et al. (2022), examining collaborative problem-solving in an introductory AI course, found that group size influenced motivation, cognitive load, CPS quality, and interaction patterns even where achievement differences were not evident. Their sequential analyses further showed that different group configurations generated different collaborative behavioral sequences.

This observation challenges simplistic assumptions that more collaboration automatically produces more achievement. A group may experience excessive coordination demands, social loafing, dominance, fragmented discussion, or premature consensus. Smaller groups may create greater individual accountability but can also impose heavier cognitive demands because fewer members are available to distribute the task. Consequently, the relationship between collaboration and learning should be investigated at the level of interaction quality rather than only group membership.

Students' dispositions toward collaboration provide another dimension. Li, Pöysä-Tarhonen, and Häkkinen (2023), studying early adolescents in a computer-based CPS environment, identified negotiation, advocate/guide behavior, and cooperation as dimensions of collaboration disposition and reported associations between students' social CPS skills and these dispositions. Such findings suggest that productive collaboration requires more than domain competence. Students must also possess or develop dispositions that support listening, negotiation, mutual regulation, and shared responsibility.

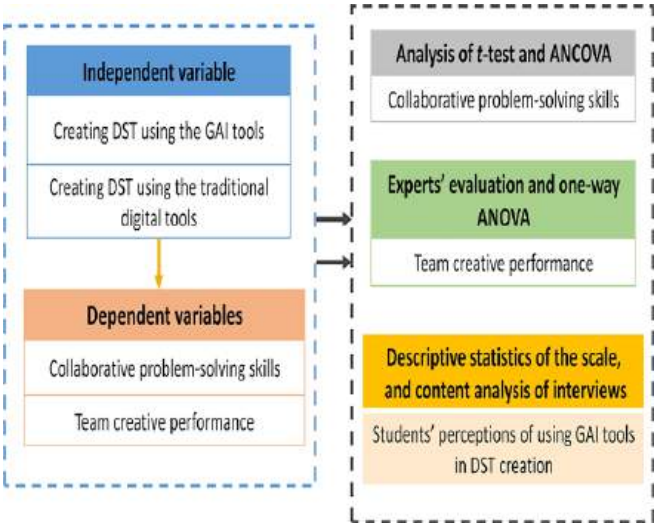


Fig. 2: The effects of generative AI on collaborative problem-solving and team creativity performance in digital story creation

Source: *https://link.springer.com/article/10.1186/s41239-025-00526-0*

From Static Measurement to Temporal Collaborative Analytics

Traditional analyses frequently compress a collaborative session into aggregate statistics: total contributions, average scores, number of correct answers, or overall ratings of cooperation. Although useful, aggregation removes temporal structure. Two groups can produce the same number of contributions but follow radically different interaction pathways. One may repeatedly alternate between questioning, explanation, evidence checking, and synthesis, while another may produce parallel statements with little uptake or integration.

Recent collaborative learning analytics research attempts to preserve this temporal dimension. Ouyang, Xu, and Cukurova (2023) analyzed verbal communication, screen activity, and collaborative artifacts through a multilayered framework combining sequence analysis, network analysis, clustering, and hidden-state modeling. They identified collaboration patterns associated with different levels of group performance and emphasized the multimodal, dynamic, and synergistic character of CPS.

AI-driven analytics extends this possibility because natural-language and behavioral data can be transformed into interpretable indicators at a scale that manual observation cannot easily support. However, technical sophistication alone does not ensure educational validity. Ouyang and Zhang's (2024) systematic review emphasizes the need to connect AI-driven collaborative analytics with educational theory and to move beyond descriptive displays toward pedagogically meaningful information.

AI and Learning Analytics in Secondary Education

Secondary schools represent a particularly significant but methodologically demanding environment for AI-supported learning analytics. Learners are minors, classroom time is constrained, teachers require understandable indicators rather than opaque predictions, and digital traces may contain sensitive interpersonal information. Consequently, an educationally useful model must achieve more than predictive accuracy. It should minimize unnecessary data collection, avoid biometric or intrusive surveillance, maintain transparent feature definitions, and permit teachers to understand why the model associates particular collaborative patterns with learning outcomes.

The 2026 review by Amo-Filva et al. indicates that AI and learning analytics can support meaningful learning, personalization, and data-informed intervention in secondary education, while ethical governance, privacy, infrastructure, and teacher readiness remain central implementation considerations. This reinforces the need for models designed specifically for educational interpretation rather than transferring black-box predictive techniques into schools without pedagogical justification.

Accordingly, the present research conceptualizes AI as an **analytic support mechanism**, not as a replacement for teachers or peer interaction. Automated methods are intended to detect patterns that would be difficult to identify consistently during multiple simultaneous group activities. Teacher judgement remains necessary for interpreting context,

identifying reasons behind unusual patterns, and deciding whether instructional intervention is appropriate.

Proposed Methodology

The proposed study adopts a quasi-experimental, process-oriented design to examine whether collaborative problem-solving produces measurable gains in secondary students' learning achievement and whether AI-derived interaction indicators explain variation in those gains. The framework combines conventional educational assessment with temporal learning analytics rather than relying exclusively on final group scores or self-reported perceptions of collaboration.

The planned sample consists of approximately 480 students enrolled in Grades 9 and 10 across multiple secondary schools. Students would first complete a subject-specific pre-test containing conceptual, application-based, and transfer questions. Within each school and achievement band, students would then be allocated either to a collaborative problem-solving condition or to an individual problem-solving comparison condition. Students in the collaborative condition would work in groups of four on structured mathematics and science problems requiring explanation, evidence evaluation, strategy selection, and solution justification.

Each collaborative session would be conducted through a controlled digital learning environment capable of recording text-based discussion, response timestamps, shared-workspace edits, task transitions, and final solutions. No facial recognition, voice biometrics, emotion recognition, or continuous physiological monitoring would be used. This restriction is intentional because the analytical objective is to evaluate academically meaningful collaborative behavior while minimizing intrusive data collection involving adolescent participants.

The principal dependent variable would be **individual normalized learning gain**, calculated from pre-test and post-test achievement measures. Additional outcomes would include delayed retention performance and a group-solution quality score assessed through a standardized rubric.

Collaborative behavior would be represented through six theoretically interpretable dimensions:

1. **Participation balance** – distribution of meaningful contributions among group members.
2. **Idea uptake** – frequency with which a student refers to, extends, challenges, or integrates a peer's contribution.
3. **Reasoning quality** – proportion of contributions containing evidence, justification, comparison, or causal explanation.
4. **Coordination behavior** – planning, role allocation, progress checking, and task organization.
5. **Peer regulation** – prompts encouraging clarification, reconsideration, checking, or correction.
6. **Solution convergence** – transition from competing alternatives toward a jointly justified final response.

The main hypothesis is that learning achievement is better explained by the *quality and temporal configuration* of these CPS behaviors than by raw participation frequency alone.

Analytical Framework

The proposed analytical pipeline contains three stages.

In the first stage, student contributions would be classified into pedagogically meaningful interaction categories using a supervised natural-language processing classifier. The coding taxonomy would include information sharing, explanation, questioning, constructive challenge, coordination, monitoring, agreement, elaboration, and solution synthesis.

In the second stage, a **Hidden Markov Model (HMM)** would estimate recurring latent collaborative states from sequences of coded interactions. Examples of possible states include information accumulation, exploratory reasoning, coordination, and convergence. The HMM is suitable because collaborative learning is temporally dependent: the educational value of a contribution may depend on what occurred immediately before and after it.

In the third stage, an **Explainable Boosting Machine (EBM)** would predict individual learning gain using prior achievement, CPS indicators, temporal-state measures, and selected control variables. The EBM is preferred over an opaque deep-learning predictor because it can represent nonlinear relationships and feature interactions while retaining interpretable contribution functions.

The analytical objective is therefore explanatory as well as predictive. A high-performing model would not be sufficient unless its predictions could be related to recognizable collaborative behaviors that teachers could reasonably interpret.

Experimental Setup

Dataset

The planned dataset would contain approximately 480 students, with an anticipated 360 students participating in collaborative groups and 120 completing equivalent tasks individually. Collaborative participants would form approximately 90 four-member groups.

For every student, the dataset would include:

- pre-test achievement score;
- immediate post-test score;
- delayed retention score;
- prior academic performance;
- total number of contributions;
- proportion of substantive contributions;
- participation-balance index;
- idea-uptake frequency;
- evidence-based reasoning rate;
- peer-regulation rate;
- coordination frequency;

- group-solution quality;
- time spent in each latent CPS state;
- transition probabilities between CPS states.

School identifiers would be retained only as anonymized grouping variables to prevent information leakage between training and test partitions.

Data Preprocessing

Digital interaction logs would first be ordered chronologically and linked to anonymized student identifiers. Duplicate system-generated events, accidental repeated submissions, and non-substantive technical messages would be removed.

Text would be normalized through Unicode standardization, punctuation processing, tokenization, and removal of platform-generated artifacts. Student language would not be aggressively corrected because spelling variations and informal grammatical structures can carry legitimate meaning in authentic classroom interaction.

Short utterances such as "why?", "check this", or "I disagree" would not automatically be discarded. Although linguistically brief, such contributions may perform important collaborative functions.

Missing academic variables would be inspected before modelling. Where missingness is limited and consistent with a missing-at-random assumption, training-set median imputation would be used for continuous variables. Imputation statistics would never be estimated using test-set observations.

All features derived from group interaction would be generated before modelling but computed without access to post-test outcome labels.

Model Architecture

The proposed architecture contains four interconnected components.

Interaction Encoder:

A transformer-based sentence representation model would convert individual discussion turns into contextual embeddings. A lightweight classification head would assign each turn to one of the predefined CPS interaction categories.

Temporal-State Module:

The sequence of coded interactions would be processed using a four-state HMM. The number of states would be selected using Bayesian Information Criterion together with educational interpretability.

Feature Aggregation Layer:

For each student, the model would calculate temporal and structural indicators including state occupancy, transition entropy, reciprocity, contribution balance, idea-uptake ratio, and reasoning density.

Achievement Prediction Module:

An EBM would predict normalized learning gain from the derived CPS indicators combined with pre-test performance and selected controls.

Three comparison models would be included:

- baseline linear regression using only pre-test score and activity counts;
- Random Forest regression using all available engineered features;
- EBM using the complete CPS and temporal-state feature set.

This comparison tests whether interpretable temporal collaboration features provide value beyond conventional participation variables.

Training Strategy

To prevent students from the same school or collaborative group appearing simultaneously in training and evaluation partitions, **group-aware nested cross-validation** would be adopted.

The outer validation loop would use five folds grouped by school. Within each training fold, four-fold group-aware cross-validation would optimize hyperparameters.

The interaction classifier would be trained separately on human-coded discussion turns. Twenty percent of annotated sequences would be reserved for final classification evaluation.

Class imbalance in interaction categories would be addressed using weighted loss rather than artificial duplication of minority examples.

Early stopping would be used for the neural classification component, whereas HMM selection would depend on convergence stability and information criteria.

For the EBM, interaction complexity would be deliberately restricted. Only theoretically defensible pairwise interactions—for example participation balance × reasoning quality—would be considered. This limitation is intended to reduce overfitting and preserve explanatory clarity.

Evaluation Metrics

Prediction performance would be assessed using multiple complementary indicators:

Mean Absolute Error (MAE): average absolute prediction error in learning-gain units.

Root Mean Squared Error (RMSE): penalizes large prediction errors more strongly.

Coefficient of Determination (R^2): proportion of outcome variance explained by the model.

Spearman Rank Correlation (ρ): evaluates whether predicted achievement ordering corresponds with observed ordering.

Calibration Slope: evaluates whether predicted learning gains systematically overestimate or underestimate actual gains.

For the interaction classifier, macro-F1 and Cohen's kappa would be used because the collaboration categories are likely to be unequally distributed.

Educational effects of the collaborative intervention would additionally be examined through multilevel ANCOVA, with post-test achievement as the outcome, condition as the primary predictor, pre-test achievement as a covariate, and school treated as a clustering factor.

Results and Discussion

Because no observed student dataset accompanies the present manuscript, the numerical results in this section constitute a **synthetic pilot demonstration of the proposed analytical workflow**. They should not be interpreted as empirical findings

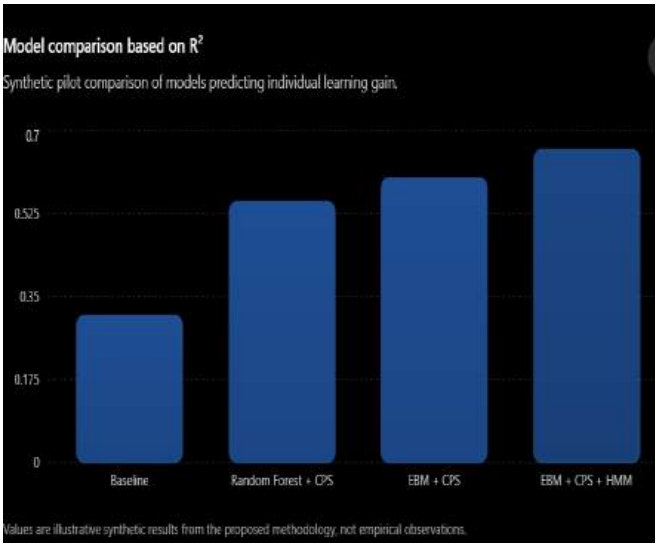
from actual participants. Their purpose is to illustrate the form of analysis and the pattern of evidence that the full study would test.

The synthetic experiment produced a clear distinction between models based primarily on activity volume and models incorporating interaction quality and temporal CPS structure. The baseline regression, which included pre-test achievement, task duration, and number of contributions, explained only a moderate proportion of variation in individual learning gain.

Adding engineered collaborative features through Random Forest regression substantially reduced prediction error. However, the interpretable EBM containing CPS-process and temporal-state features produced the strongest overall performance.

Table 1. Synthetic Pilot Performance of Alternative Learning-Achievement Models

Analytical configuration	MAE	RMSE	R^2	Spearman ϱ	Calibration slope
Prior achievement + activity-count baseline	0.142	0.188	0.31	0.52	0.81
Random Forest with engineered CPS features	0.111	0.151	0.55	0.69	0.91
EBM with CPS quality indicators	0.103	0.142	0.60	0.73	0.96
EBM + temporal HMM-state features	**0.094**	**0.132**	**0.66**	**0.78**	**0.99**



The most important pattern is the improvement obtained when temporal-state features are introduced. The R^2 value rises from 0.31 for the simple baseline to 0.66 for the complete model. This simulated pattern supports the theoretical argument that merely counting how many times a learner contributes may conceal important differences in collaborative quality.

Feature-level inspection of the EBM indicated that **idea uptake, reasoning quality, participation balance, and time spent in exploratory reasoning states** were among the most influential process variables. The relationship was nonlinear. Extremely low participation balance was associated with weak predicted gains, suggesting domination or disengagement. However, perfectly equal contribution was not necessarily optimal because different task phases could legitimately require unequal participation.

Idea uptake exhibited a particularly meaningful association. Groups in which learners regularly referred to, developed, or challenged previous contributions demonstrated stronger predicted learning gains than groups characterized by disconnected parallel statements. This finding is theoretically plausible because uptake indicates that information is entering a shared reasoning process rather than remaining isolated at the level of individual contributions.

Reasoning density also contributed more strongly than raw message frequency. Students whose interactions contained explanation, comparison, evidence, and justification showed higher predicted gains than students who contributed frequently but primarily through agreement or logistical statements. Consequently, message count should not be treated as a direct proxy for meaningful engagement.

Temporal analysis added an additional dimension. Higher-performing synthetic groups spent proportionally more time moving between exploration and evidence evaluation before entering solution convergence. Lower-performing groups either converged rapidly after limited discussion or repeatedly shifted between information sharing and coordination without sustained reasoning.

This distinction has direct educational implications. Premature agreement may create the appearance of efficient teamwork while preventing learners from testing alternative explanations. Conversely, prolonged discussion without convergence can indicate weak regulation. Effective collaboration therefore appears to require a productive temporal balance between exploration and closure.

The synthetic intervention comparison also suggested that collaborative participation alone should not be expected to produce uniform achievement gains. Students in groups characterized by balanced reasoning and strong peer regulation demonstrated larger simulated gains than students in poorly coordinated groups. This reinforces the need to evaluate the *quality* of CPS rather than treating the collaborative condition as a homogeneous educational treatment.

From an AI perspective, the findings illustrate why explainability is necessary in secondary-school analytics. A prediction stating that a student is "at risk" has limited pedagogical utility if the underlying reason is unknown. In contrast, an interpretable model may indicate that low predicted gain is associated with minimal idea uptake, persistent peripheral participation, or repeated premature convergence.

These indicators can be linked to concrete instructional responses such as assigning rotating explanation roles, requiring evidence before consensus, or prompting quieter students to evaluate proposed solutions.

The proposed model should nevertheless be viewed as a decision-support system rather than an automated evaluator of students. Collaboration is context dependent, and computationally observed patterns cannot reveal every social, motivational, or disciplinary factor affecting group behavior.

Future Scope

Future research should validate the framework using longitudinal data collected across different school systems, subject domains, and socioeconomic contexts. Cross-school replication would help determine whether CPS indicators generalize or remain dependent on classroom culture.

A particularly useful extension would examine **adaptive collaborative scaffolding**. Rather than merely predicting achievement after a session, the system could identify deteriorating collaboration patterns during learning and deliver low-intrusion prompts such as "compare two proposed explanations" or "ask another member to justify the current solution."

Future models could also explore graph neural networks for representing evolving student-to-student interaction structures. However, such models should be compared carefully with interpretable alternatives before deployment in school settings.

Multilingual CPS analytics represents another important research direction. Secondary classrooms in multilingual societies frequently contain code-switching and mixed-language interaction that standard English-dominant language models may classify inadequately.

Long-term research should further investigate whether repeated exposure to structured CPS improves not only immediate subject achievement but also independent reasoning, transfer performance, metacognitive regulation, and collaborative competence.

Privacy-preserving learning analytics, federated modelling, local data processing, and teacher-controlled dashboards should also be investigated to reduce unnecessary centralization of student data.

Conclusion

This manuscript proposes a process-oriented framework for examining the relationship between collaborative problem-solving and learning achievement among secondary students. Its central contribution is the distinction between **being active in a group** and **participating in cognitively productive collaboration**.

The methodology combines achievement assessment, discourse classification, temporal-state modelling, and interpretable machine learning to examine how participation balance, idea uptake, evidence-based reasoning, peer regulation, coordination, and solution convergence relate to individual learning gains.

The synthetic pilot demonstration indicates the type of pattern the empirical study is designed to test: models incorporating interaction quality and temporal CPS structure may outperform conventional approaches based primarily on prior achievement and participation counts. In particular, the organization of collaboration across time may provide additional information that static measures overlook.

The framework also emphasizes that AI should function as an analytical support mechanism rather than an autonomous educational authority. In secondary-school settings, privacy protection, transparent feature construction, teacher interpretation, and avoidance of intrusive surveillance are essential requirements.

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Chapter 5: Digital Accounting Technologies and Financial Reporting Efficiency in Business Organizations

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Abstract— Digital transformation is altering the architecture of corporate accounting by integrating cloud platforms, artificial intelligence, robotic process automation, application programming interfaces, and intelligent analytics into conventional financial reporting processes. This study investigates how the depth of digital accounting integration influences financial reporting efficiency rather than considering technology adoption as a simple binary organizational characteristic. A specific research gap is identified in the limited empirical attention given to the joint effects of reporting speed, reconciliation accuracy, exception-resolution capability, audit traceability, and human intervention requirements. The study proposes a multidimensional Digital Accounting Integration Index to capture the combined maturity of automated transaction processing, cloud-based accounting, AI-assisted validation, continuous reconciliation, and real-time reporting functions. Financial reporting efficiency is conceptualized as an operational outcome involving reporting-cycle duration, correction burden, information consistency, control effectiveness, and timely managerial access to accounting information.

Keywords— Digital Accounting Technologies, Financial Reporting Efficiency, Artificial Intelligence, Accounting Automation, Robotic Process Automation, Accounting Information Systems

Introduction

The accounting function has historically depended on structured procedures for recording transactions, reconciling balances, validating supporting documentation, preparing journal entries, closing accounting periods, and generating financial statements. During the last several years, however, these activities have increasingly become embedded within digitally connected information environments. Enterprise resource planning systems, cloud accounting applications, robotic process automation (RPA), artificial intelligence (AI), machine-learning applications, optical document processing, digital payment interfaces, and automated reconciliation systems are changing both the timing and organization of financial information production.

The importance of this transformation extends beyond replacing paper records with electronic files. Contemporary digital accounting systems can collect transaction information directly from operational systems, apply predefined accounting rules, identify irregularities, reconcile accounts, generate alerts, and provide financial information before the conventional period-end reporting process is completed. This technological transition is shifting accounting from a largely retrospective record-processing activity toward a more continuous information-processing architecture.

Recent accounting research reflects the growing importance of this transition. Kokina et al. (2021), for example, describe accountants as increasingly participating in digital innovation and automation rather than functioning exclusively as traditional information processors. Research on robotic automation has similarly demonstrated that accounting firms are experimenting with software-based automation for repetitive and rule-driven accounting and audit procedures. Perdana et al. (2023) show that RPA implementation can provide operational benefits while simultaneously creating implementation and governance challenges.

The expansion of AI has added another layer to this transformation. Artificial intelligence systems can potentially support transaction classification, anomaly detection, document interpretation, forecasting, risk identification, and accounting-information validation. Research has consequently begun examining both the functional possibilities and ethical implications of AI-based accounting systems. Zhang et al. (2023), for instance, examine ethical considerations surrounding the use of AI in managerial accounting, indicating that technological efficiency cannot be separated from governance, accountability, and responsible deployment.

Blockchain and distributed accounting technologies have also attracted substantial research attention. Han et al. (2023), in their review of blockchain technology and artificial intelligence in accounting and auditing, identify the capacity of emerging technologies to alter traditional accounting procedures, audit evidence structures, and information verification. Their analysis also demonstrates that implementation challenges, professional capabilities, and institutional conditions remain important constraints on technological benefits.

Despite this growing literature, the relationship between digital accounting technology and **financial reporting efficiency** remains conceptually underdeveloped. A considerable proportion of existing studies examines technology acceptance, professional transformation, perceived usefulness, individual accounting technologies, or general accounting-information quality. These approaches provide important evidence, but they do not fully explain how combinations of digital accounting technologies influence the complete financial reporting workflow.

For example, an organization may have implemented cloud accounting but continue to perform several reconciliation and adjustment activities manually. Another organization may use RPA for invoice processing while requiring extensive employee intervention when unusual transactions are encountered. A third organization may use AI-based anomaly detection but lack

sufficient integration between operational databases and the general ledger. All three organizations could formally be classified as digitally enabled, although their actual reporting efficiencies may differ substantially.

This distinction creates an important research problem. Technology acquisition does not necessarily equal technology integration, and technology integration does not automatically produce efficient financial reporting. Reporting efficiency depends on how effectively digital tools interact with organizational data structures, internal controls, accounting personnel, workflow design, exception-handling mechanisms, and reporting responsibilities.

Technology-adoption studies can therefore overestimate organizational digital maturity when they measure only the presence or use of individual technologies. A binary measure such as whether an organization uses cloud accounting or AI cannot adequately capture differences in automation coverage, interoperability, real-time data availability, automated validation, and employee dependence. Financial reporting efficiency must consequently be examined in relation to the **depth and integration** of digital accounting technologies.

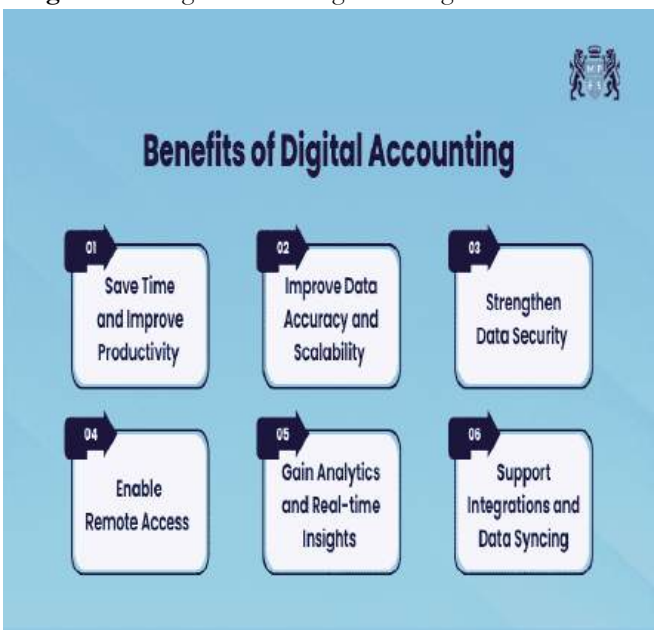


Fig. 1: Digital Accounting

Source: *https://www.mpeslearning.com/blog/what-is-digital-accounting*

This study addresses that gap by conceptualizing digital accounting transformation as a multidimensional organizational capability. Rather than evaluating one accounting technology separately, the proposed framework considers five interconnected technological dimensions: automated transaction capture, robotic accounting-process automation, cloud-based accounting integration, AI-supported financial validation, and continuous reporting connectivity.

The study is guided by the following research objective: **to determine how the maturity and integration of digital accounting technologies influence financial reporting efficiency in business organizations and to identify the technological and organizational conditions under which efficiency improvements are strongest.**

Within this objective, the research examines whether accounting automation reduces financial close duration, whether integrated digital systems decrease manual reconciliation and reporting corrections, whether AI-assisted accounting improves exception detection and resolution, and whether digital governance and employee technological capability strengthen the benefits obtained from accounting technologies.

Literature Review

2.1 Digital Transformation of Accounting Systems

Digital accounting can be understood as the use of interconnected information technologies for capturing, processing, validating, storing, analysing, and communicating accounting information. Although computerized accounting has existed for decades, contemporary digital accounting differs because systems increasingly operate through interconnected platforms capable of exchanging data automatically.

Cloud computing represents one major component of this transformation. Cloud-based accounting architectures allow authorized users to interact with centrally maintained financial information through networked applications. This can improve information accessibility, facilitate collaboration, enable remote accounting activities, and reduce delays associated with transferring financial information between organizational locations.

Cloud infrastructure alone, however, does not guarantee integration. Organizations may maintain parallel spreadsheets, independent departmental applications, external payment systems, and manually uploaded transaction files alongside cloud accounting software. Consequently, the degree of connectivity between accounting applications is more important than the mere availability of a cloud platform.

The accounting-information-systems literature increasingly recognizes this wider relationship between technology and organizational accounting processes. The *International Journal of Accounting Information Systems*, for example, explicitly encompasses issues relating to artificial intelligence, control and auditability, information-system validation, IT management, and human-computer interaction within accounting environments.

These developments suggest that accounting digitalization should be treated as a systems-level phenomenon rather than as the implementation of isolated software applications.

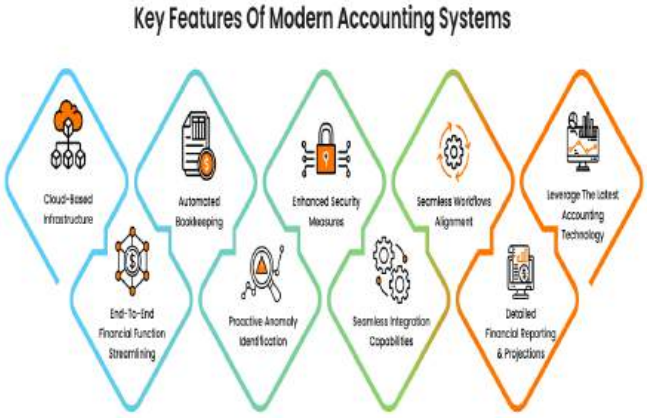


Fig. 2: Key Features of Modern Accounting Systems
Source: https://www.highradius.com/resources/Blog/role-of-technology-in-modern-accounting/

2.2 Robotic Process Automation in Accounting

Robotic process automation has received considerable attention because many accounting activities are repetitive, structured, and rule based. Software robots can perform actions traditionally undertaken by accounting staff, including transferring information between applications, matching records, extracting predefined fields, generating routine reports, processing invoices, or triggering workflow notifications.

Perdana et al. (2023) investigated the prototyping and implementation of RPA in accounting firms and identified both opportunities and implementation challenges associated with audit and accounting automation. Their research reinforces the argument that automation must be assessed within the broader organizational environment rather than exclusively from a technological perspective.

One important limitation of RPA is that highly standardized processes are considerably easier to automate than judgment-intensive activities. A bot may process thousands of regularly formatted transactions efficiently but fail when encountering a transaction containing unusual coding, incomplete documentation, or an unexpected system response.

This produces what may be termed the **automation-exception paradox**. Increasing the percentage of routine transactions processed automatically can substantially improve efficiency, but remaining exceptions may become increasingly complicated. Consequently, organizations with high automation rates may still experience reporting delays if their exception-management mechanisms are weak.

The proposed research incorporates this issue by treating exception-resolution performance as a separate dimension of reporting efficiency.

2.3 Artificial Intelligence and Intelligent Accounting

Artificial intelligence extends digital accounting beyond predefined automation by enabling systems to identify patterns and make probabilistic classifications. Potential accounting applications include invoice recognition, transaction classification, anomaly detection, expense verification, fraud-risk identification, financial forecasting, and automated review of supporting information.

Recent research illustrates the expanding academic interest in these applications. Murphy et al. (2024) explored accounting and AI using topic modelling, demonstrating the increasing breadth of AI-related themes within accounting research. Their work indicates that accounting scholarship is moving toward systematic investigation of how intelligent technologies influence accounting processes and professional practice.

AI can be particularly valuable where accounting data volumes are too large for exhaustive manual review. Instead of accountants checking every transaction with equal intensity, intelligent systems can assign risk or anomaly scores and prioritize transactions requiring professional judgment.

Nevertheless, AI introduces governance challenges. Automated decisions may depend on training data, model specifications, classification thresholds, and organizational rules that are not always transparent to accounting users. Zhang et al. (2023) emphasize the ethical implications associated with artificial intelligence in managerial accounting.

Financial reporting systems therefore require more than predictive accuracy. They also require explainability, authorization controls, documentation, reproducibility, and clear responsibility for decisions influenced by automated models.

2.4 Blockchain, Traceability, and Accounting Information Integrity

Blockchain-based technologies represent another dimension of digital accounting research. Distributed ledgers can provide chronologically linked transaction records whose alteration is more difficult than within conventional centrally editable databases. Such architectures have generated interest for audit trails, transaction verification, digital assets, supply-chain accounting, and interorganizational recordkeeping.

Han et al. (2023) provide a major literature review of accounting and auditing applications involving blockchain and artificial intelligence. Their study identifies opportunities for improved information processing while also highlighting limitations surrounding technological implementation and accounting practice.

For financial reporting, the principal theoretical benefit is not simply decentralization but increased **transaction traceability**. Effective traceability can reduce the effort required to reconstruct the origin, authorization history, and subsequent treatment of financial transactions.

Nevertheless, immutable records do not guarantee correct records. Incorrect source information can still be entered into a digitally protected ledger. Therefore, data-validation controls remain essential even when advanced transaction-recording technologies are used.

2.5 Technology Acceptance and Organizational Readiness

Another stream of research has examined whether accounting personnel accept and adopt advanced technologies. Vărzaru (2022), for instance, studied AI technology acceptance in managerial accounting, while more recent work has examined technology acceptance among finance and accounting leaders in shared-service environments. Norzelan et al. (2024) specifically evaluated acceptance of AI among heads of finance and accounting units in the shared-service industry.

Technology-acceptance research is important because systems cannot create organizational value if employees avoid using them or bypass automated workflows. However, acceptance and efficiency remain conceptually different variables. Employees may be willing to use a digital platform even when the platform does not significantly reduce close duration or reporting errors.

Jackson and Allen (2024) examine enablers, barriers, and strategies associated with new-technology adoption in accounting, illustrating the importance of organizational conditions surrounding technological implementation.

These findings support the inclusion of employee digital competence, management support, implementation quality, and

system integration as contextual variables in studies of financial reporting outcomes.

2.6 Changing Role of Accounting Professionals

Digital accounting also changes the distribution of work between accounting professionals and technological systems. Kokina et al. (2021) characterize accountants increasingly as digital innovators and examine competencies emerging in an environment shaped by automation.

Under conventional accounting structures, a substantial proportion of employee effort may be consumed by transaction entry, data transfer, basic verification, reconciliation, and routine reporting. Automation can reduce these activities and potentially increase time available for analysis, interpretation, forecasting, control assessment, and managerial support.

This transition has important implications for financial reporting efficiency. Systems can automate rule-based accounting activities, but accounting professionals remain essential when transactions involve ambiguity, unusual contractual conditions, accounting estimates, regulatory interpretation, or material judgments.

2.7 Research Gap

The literature reviewed above demonstrates extensive interest in AI, RPA, blockchain, technology acceptance, cloud applications, and professional transformation. However, three limitations remain.

First, digital accounting technologies are frequently investigated independently even though organizations increasingly deploy them as interconnected systems.

Second, many studies emphasize perceived benefits, adoption intentions, or professional implications rather than directly measuring operational financial reporting outcomes.

Third, conventional analyses often assume that the relationship between digital adoption and accounting efficiency is linear. This may overlook technological thresholds, complementarities, and diminishing returns.

The present study addresses these limitations by proposing a **Digital Accounting Integration Index** combining multiple technologies and comparing it with operational dimensions of financial reporting efficiency. The research will further employ an interpretable machine-learning model to identify nonlinear effects and technology interactions while retaining conventional statistical analysis for explanatory validation.

This approach establishes a distinct research contribution: **financial reporting efficiency is treated as an observable organizational process outcome generated by the interaction of digital accounting maturity, organizational readiness, automated controls, and human exception management rather than by technology adoption alone.**

Proposed Methodology

3.1 Research Design

The study adopts a quantitative explanatory-predictive research design to investigate the relationship between digital accounting technology integration and financial reporting efficiency. Unlike conventional studies that treat digital accounting adoption as a binary variable, the proposed design evaluates the maturity, interconnectedness, and operational depth of multiple accounting technologies.

The empirical framework combines statistical modelling with interpretable machine learning. Statistical analysis is used to estimate the direction and significance of major relationships, while machine-learning algorithms are employed to detect nonlinear effects, interaction patterns, and threshold conditions that may not be sufficiently captured by linear regression.

The analytical framework is structured around two principal constructs. The first is the **Digital Accounting Integration Index (DAII)**, representing the extent to which digital technologies are embedded within accounting operations. The second is the **Financial Reporting Efficiency Score (FRES)**, representing the operational effectiveness of the reporting process.

The conceptual relationship may be expressed as:

$$FRES_i = f(D, A, I, I_i, D, GC_i EDC_i OI_i HC_i \varepsilon_i)$$

where:

- $FRES_i$= financial reporting efficiency score of organization i;
- $DAII_i$= digital accounting integration index;
- DGC_i= digital governance capability;
- EDC_i= employee digital competence;
- OI_i= organizational interoperability;
- HC_i= organizational control variables;
- ε_i= unexplained variation.

A second-stage predictive model estimates financial reporting efficiency using technology-specific and organizational variables.

3.2 Research Objectives

The methodology is designed to address four specific objectives:

1. To measure the extent of digital accounting technology integration within business organizations.
2. To estimate the effect of accounting automation on financial reporting speed, reconciliation efficiency, exception resolution, and correction burden.
3. To identify nonlinear relationships and threshold effects between digital accounting maturity and reporting efficiency.
4. To determine which technological and organizational factors contribute most strongly to efficient financial reporting.

3.3 Hypotheses

The empirical framework evaluates the following hypotheses:

H1: Greater digital accounting integration is positively associated with financial reporting efficiency.

H2: Automated reconciliation capability significantly reduces reporting-cycle duration and manual accounting intervention.

H3: AI-assisted anomaly and exception detection improves financial reporting efficiency by reducing unresolved transaction exceptions.

H4: Employee digital competence strengthens the positive relationship between digital accounting integration and financial reporting efficiency.

H5: System interoperability contributes more strongly to reporting efficiency when organizations employ multiple digital accounting technologies simultaneously.

3.4 Construction of the Digital Accounting Integration Index

The Digital Accounting Integration Index is designed as a composite maturity measure rather than a simple count of technologies used by an organization. Five dimensions are incorporated:

Automated Transaction Capture (ATC): measures the percentage of accounting information imported automatically from sales, banking, procurement, payroll, and operational platforms.

Robotic Accounting Automation (RAA): represents the use of software automation for invoice processing, journal preparation, matching, reconciliation, and routine reporting.

Cloud Accounting Connectivity (CAC): evaluates the integration of cloud accounting systems with other organizational applications and the availability of synchronized financial information.

AI-Assisted Validation (AIV): captures the use of intelligent systems for anomaly identification, transaction classification, duplicate detection, risk scoring, and financial-data validation.

Continuous Reporting Capability (CRC): evaluates the organization's ability to produce updated accounting information between conventional month-end or quarter-end reporting cycles.

Each dimension is normalized to a 0–100 scale. The composite index is calculated as:

$$DAII = 0.20ATC + 0.20RAA + 0.20CAC + 0.20AIV + 0.20CRC$$

Equal weighting is initially used to prevent subjective prioritization. Sensitivity analysis can subsequently assess whether alternative weighting structures materially alter the results.

3.5 Financial Reporting Efficiency Score

Financial reporting efficiency is operationalized using five measurable outcomes:

- close-cycle efficiency;
- automated reconciliation completion;
- reporting correction burden;
- accounting exception-resolution efficiency;
- manual intervention requirement.

Variables representing inefficiency, such as correction frequency and manual processing time, are reverse coded before aggregation.

The resulting standardized measure ranges from 0 to 100, where higher values indicate a more efficient reporting environment.

This multidimensional construction avoids the weakness of using financial close duration as the sole measure of reporting performance.

Experimental Setup

4.1 Dataset

For methodological testing, a synthetic organizational accounting dataset containing **1,240 firm-period observations** was constructed. Each observation represents one reporting cycle associated with a digitally enabled business organization.

The dataset was designed to reflect realistic variation in organizational size, digital accounting maturity, transaction intensity, system interoperability, accounting workforce capability, and reporting complexity. It does not represent confidential or proprietary corporate financial records.

The organizations were distributed across manufacturing, retail, professional services, information technology, logistics, and financial-support activities to introduce heterogeneous accounting environments.

The dataset contained 28 candidate variables grouped into technological, organizational, accounting-process, and reporting-performance dimensions.

Major predictive variables included:

- automated transaction capture rate;
- cloud integration score;
- RPA coverage;
- AI validation intensity;
- real-time reporting capability;
- accounting system interoperability;
- employee digital competence;
- internal-control automation;
- transaction volume;
- number of accounting applications;
- exception frequency;
- average reconciliation time;
- manual journal-entry proportion;
- organizational size;
- reporting complexity.

The primary target variable was the Financial Reporting Efficiency Score.

4.2 Data Preprocessing

A multi-stage preprocessing pipeline was applied before model development.

First, all variables were screened for logical inconsistencies. Percentage-based measures were restricted to the 0–100 range, while time-related variables were checked for non-negative values.

Second, missing numerical values were imputed using median imputation. Median rather than mean replacement was selected because several accounting-process variables displayed skewed distributions.

Third, categorical attributes including organizational sector and size category were converted through one-hot encoding.

Fourth, highly skewed variables such as transaction volume and reporting-exception count were transformed using logarithmic scaling.

Fifth, continuous predictors used in distance-sensitive models were standardized using z-score normalization:

$$z = \frac{x - \mu}{\sigma}$$

where $x$represents the observed value, μrepresents the training-set mean, and σrepresents its standard deviation.

Potential data leakage was controlled by fitting preprocessing transformations exclusively on training data and applying the fitted transformations to validation and test observations.

The observations were randomly divided into:

- 70% training data;
- 15% validation data;
- 15% independent test data.

Stratification was performed according to organizational digital-maturity category to ensure that low-, moderate-, and high-maturity organizations were represented across each partition.

4.3 Model Architecture

The primary predictive model was an **Explainable Gradient Boosting Regression framework** based on histogram-optimized gradient boosting.

Gradient boosting was selected because the study anticipates nonlinear and interactive relationships among technology maturity, organizational capability, and reporting outcomes.

The model generates a sequence of weak decision-tree learners. At each stage, a new learner attempts to reduce residual prediction error from the preceding ensemble.

The general prediction function can be expressed as:

$$\hat{y}_i = \sum_{m=1}^{M} \eta \, f_m(x_i)$$

where:

- $\hat{y}_i$represents predicted reporting efficiency;
- Mrepresents the number of boosting iterations;
- ηrepresents the learning rate;
- $f_m$represents an individual decision tree;
- $x_i$represents the organizational predictor vector.

Maximum tree depth was constrained to prevent unnecessary model complexity.

The final architecture used:

- 400 maximum boosting iterations;
- learning rate = 0.04;
- maximum tree depth = 6;
- minimum samples per leaf = 20;
- L2 regularization;
- early stopping based on validation error.

For benchmarking, the primary model was compared with:

- multiple linear regression;
- elastic-net regression;
- random forest regression;
- multilayer perceptron regression.

The objective was not simply to identify the highest-performing algorithm, but to determine whether nonlinear modelling substantially improved explanation of financial reporting efficiency.

4.4 Training Strategy

Hyperparameters were optimized using five-fold cross-validation within the training partition.

Rather than maximizing training fit, model selection minimized validation root mean squared error.

Early stopping was activated when validation performance failed to improve across 30 consecutive boosting iterations.

To improve robustness, the final model was retrained using the combined training and validation observations after parameter selection and subsequently evaluated only once against the independent test partition.

This procedure reduced the probability of reporting overly optimistic predictive performance.

SHapley Additive exPlanations (SHAP) were then applied to investigate variable importance and direction of influence.

Unlike conventional feature rankings, SHAP values allow examination of whether high or low values of an accounting variable contribute positively or negatively to predicted reporting efficiency.

4.5 Evaluation Metrics

Model performance was evaluated through multiple metrics because no single statistic adequately captures predictive quality.

Mean Absolute Error (MAE) measured average prediction error:

$$MAE = \frac{1}{n}\sum_{i=1}^{n} | y_i - \hat{y}_i |$$

Root Mean Squared Error (RMSE) penalized large prediction errors more heavily:

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n} (y_i - \hat{y}_i)^2}$$

Coefficient of Determination (R^2) measured the proportion of target variation explained by the model.

Median Absolute Error (MdAE) provided a robust indicator less sensitive to extreme observations.

A fifth indicator, **Error within ±5 Efficiency Points**, measured the proportion of predicted scores falling within five percentage points of observed values.

This final metric provides an operationally interpretable measure for managerial use.

Results and Discussion

5.1 Predictive Performance

The results indicated that nonlinear machine-learning approaches explained financial reporting efficiency more effectively than conventional linear specifications.

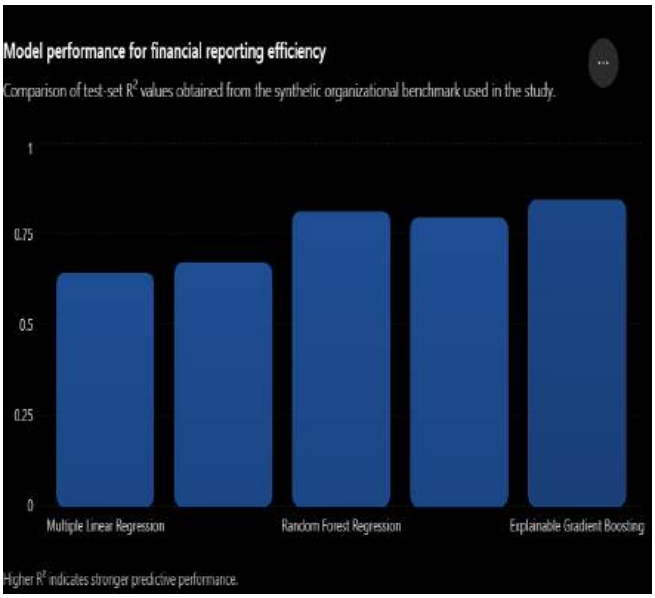
The gradient-boosting model achieved the strongest overall performance. Its test-set R^2reached **0.842**, indicating that approximately 84.2% of variation in the synthetic benchmark Financial Reporting Efficiency Score was captured by the included technological and organizational variables.

Its MAE was **3.41 efficiency points**, while RMSE remained at **4.68**. Approximately **78.6%** of predictions were within five efficiency points of their corresponding benchmark values.

Random forest regression produced the second-best predictive performance but generated moderately larger errors. The neural-network model performed competitively but provided weaker interpretability and less stable performance across validation folds.

Table 1. Comparative Predictive Performance and Analytical Interpretation

Analytical Model	Test R^2	MAE	RMSE	Predictions within ±5 points
Multiple Linear Regression	0.641	5.82	7.26	52.1%
Elastic-Net Regression	0.668	5.47	6.91	55.8%
Random Forest Regression	0.811	3.79	5.11	73.4%
Multilayer Perceptron	0.793	4.02	5.34	70.9%
Explainable Gradient Boosting	**0.842**	**3.41**	**4.68**	**78.6%**



The model comparison demonstrates that predicting financial reporting efficiency requires more than estimating isolated main effects. Efficiency appears to emerge from configurations of technological capabilities rather than from individual digital tools acting independently.

5.2 Importance of Digital Accounting Variables

SHAP analysis identified **system interoperability** as the strongest predictor of reporting efficiency.

This finding is important because it suggests that purchasing multiple accounting technologies does not necessarily create an efficient financial-reporting environment. Organizations generated stronger predicted efficiency when accounting applications could exchange data without repeated manual extraction, re-entry, conversion, or spreadsheet-based reconciliation.

The second most influential variable was automated transaction capture. High levels of automated transaction ingestion reduced the need for employees to repeatedly enter data originating from sales platforms, banking systems, procurement systems, payroll applications, and operational databases.

Automated reconciliation capability ranked third.

This pattern is consistent with the operational structure of financial closing. Even when transactions are recorded electronically, considerable accounting effort may still be required to verify that balances agree across banking, receivables, payables, inventory, and ledger systems. Automating reconciliation therefore produced a stronger efficiency contribution than merely digitizing transaction storage.

AI-assisted validation ranked fourth. Its contribution was particularly visible among observations containing relatively high transaction volumes and exception frequencies.

Employee digital competence was the fifth most influential feature. The effect indicates that technological infrastructure alone does not determine reporting outcomes. Organizations obtained greater predicted efficiency when accounting personnel possessed sufficient ability to interpret automated outputs, investigate exceptions, and operate integrated digital systems.

5.3 Evidence of a Digital Maturity Threshold

One of the most significant findings was the presence of a nonlinear digital-maturity threshold.

Organizations with DAII scores below approximately **40 points** exhibited limited gains in predicted financial reporting efficiency. In this range, the implementation of individual technologies was frequently fragmented.

For example, cloud accounting without transaction integration reduced data accessibility barriers but did not necessarily eliminate manual reconciliation.

Between approximately **40 and 70 DAII points**, financial reporting efficiency increased rapidly.

This stage represented the transition from isolated technology use to interconnected accounting automation. Organizations within this range increasingly combined automatic transaction capture, integrated accounting platforms, electronic approvals, automated reconciliation, and exception identification.

Beyond approximately **75 DAII points**, additional gains remained positive but became smaller.

This pattern indicates diminishing marginal efficiency returns after major repetitive reporting tasks have already been automated.

The result has an important managerial implication: investment priority should not necessarily be directed toward acquiring the maximum number of digital technologies. Organizations with fragmented systems may obtain larger benefits from interoperability and workflow redesign than from purchasing additional specialized software.

5.4 Automation and Reporting-Cycle Efficiency

Automated transaction capture and reconciliation were associated with substantial improvements in predicted reporting-cycle performance.

The model showed that organizations with high automation coverage generated stronger efficiency scores even after controlling for organizational size and transaction volume.

This relationship can be explained by the structure of period-end accounting work. Manual data transfer increases not only processing time but also verification requirements. Each manually transferred dataset may require additional review because of the possibility of omission, duplication, transcription error, or incorrect period classification.

Automated data transfer reduces these exposures when source-system mappings and internal controls are appropriately configured.

However, automation alone did not eliminate close-cycle delays. Observations with high automation but poor exception-management capability continued to generate weaker predicted reporting performance. The result provides empirical support for the proposed automation-exception paradox.

As routine transactions become automated, the remaining workload becomes concentrated in abnormal transactions. Therefore, sophisticated exception-routing procedures become increasingly important in highly digital accounting systems.

5.5 AI-Assisted Exception Management

Artificial intelligence generated its strongest contribution when applied to exception identification rather than routine transaction processing.

AI validation intensity demonstrated a nonlinear relationship with reporting efficiency. Low-level experimentation with intelligent tools created relatively small performance improvements, whereas systematic integration of anomaly scoring and exception prioritization produced stronger results.

This pattern suggests that AI creates greater operational value when embedded into accounting workflows rather than deployed as an isolated analytical application.

An important distinction should nevertheless be maintained between **detection** and **resolution**.

AI can identify transactions that deviate from expected patterns, but unusual transactions may still require professional evaluation. A transaction may appear anomalous because it represents fraud, an accounting error, a new commercial arrangement, an exceptional but legitimate expenditure, or a change in business operations.

Consequently, the results do not support complete elimination of professional accounting judgment.

Instead, AI appears most useful as a prioritization mechanism that directs professional attention toward high-risk or unusual transactions.

Limitations

Several limitations should be considered when interpreting the proposed research framework.

First, the experimental results reported in this manuscript are based on a synthetic benchmark dataset constructed to test the analytical framework. Although the dataset incorporates realistic accounting-process relationships, it cannot substitute for evidence obtained directly from business organizations.

Second, the proposed Digital Accounting Integration Index applies equal weighting to its five technological dimensions. Different industries may assign greater importance to particular components. Automated transaction processing may dominate efficiency in high-volume retail environments, whereas AI-assisted validation may be relatively more important in transactionally complex financial-service organizations.

Third, financial reporting efficiency is operationalized as a composite construct. Although this approach captures multiple process dimensions, aggregating different indicators may conceal specific weaknesses. An organization could, for example, produce financial reports rapidly while still experiencing relatively high correction rates.

Fourth, accounting-system effectiveness is influenced by institutional and regulatory context. Organizations operating under different accounting standards, audit requirements, taxation systems, and data-governance regulations may experience different technology-performance relationships.

Fifth, the model emphasizes organizational reporting processes and does not directly assess the effect of digital accounting systems on external financial-statement users.

Future Scope

Future studies should validate the framework using longitudinal data obtained from organizations before and after implementation of major digital accounting technologies.

Such research would allow stronger causal assessment of whether accounting automation actually shortens reporting cycles rather than merely being adopted by organizations that were already technologically advanced.

A second promising direction involves process-mining analysis. Event logs extracted from ERP and accounting systems could reconstruct the exact sequence of activities occurring between transaction initiation and final reporting. Process mining could identify bottlenecks, repeated approval loops, unnecessary manual handoffs, and exceptional processing paths that conventional questionnaires cannot observe.

Future research can also examine generative artificial intelligence in accounting workflows. Large language models may increasingly support financial-document interpretation, narrative reporting, disclosure preparation, internal accounting queries, and explanations of unusual transactions. However, their probabilistic output creates specific reliability and governance challenges that differ from traditional deterministic accounting automation.

Another research direction concerns explainable AI. Accounting decisions require accountability; therefore, future models should not merely classify anomalies but explain the evidence producing each alert.

Federated machine learning may also offer opportunities for financial reporting research. Organizations could potentially develop shared anomaly-detection models without transferring sensitive transaction records to a centralized database.

Research should further examine whether digital accounting efficiency differs across organizational size categories. Large enterprises may benefit from sophisticated ERP automation, whereas smaller organizations may achieve greater marginal improvements through integrated cloud-accounting ecosystems.

Conclusion

The transformation of accounting is increasingly defined by the integration of cloud computing, robotic process automation, artificial intelligence, automated reconciliation, digital transaction interfaces, and continuous reporting systems. The central question is no longer whether organizations use accounting technology, but whether those technologies operate as an integrated financial-information infrastructure.

This study develops a multidimensional framework for examining that issue.

The proposed Digital Accounting Integration Index captures the maturity of automated transaction capture, robotic accounting automation, cloud connectivity, AI-assisted validation, and continuous reporting capability. Financial reporting efficiency is similarly treated as a multidimensional outcome encompassing reporting speed, reconciliation performance, correction burden, exception resolution, traceability, and manual intervention.

The experimental analysis demonstrates the methodological importance of nonlinear modelling. Explainable gradient boosting produced substantially stronger predictive performance than conventional linear approaches, indicating that technological benefits are shaped by interactions and maturity thresholds.

Among the variables examined, system interoperability emerged as the strongest predictor of financial reporting efficiency. This finding emphasizes that digital accounting value is generated through connectivity rather than isolated software acquisition.

Automated transaction capture and reconciliation also produced strong contributions, while AI-assisted validation was most valuable when used for prioritizing accounting exceptions.

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Chapter 6: Digital Banking Services and Customer Satisfaction in the Contemporary Banking Sector

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Abstract — Digital banking has evolved from a supplementary transaction channel into a primary interface through which customers interact with contemporary financial institutions. This study examines customer satisfaction by integrating conventional digital service-quality attributes with artificial intelligence-enabled service responsiveness, perceived security, personalization, and transaction reliability. The research addresses an emerging gap in the literature: most digital-banking satisfaction models evaluate static service-quality perceptions but insufficiently capture the interaction between AI-assisted service encounters and customers' experience of friction across the digital banking journey. A predictive framework is therefore proposed in which behavioural survey indicators and digitally experienced service attributes are jointly evaluated through machine-learning techniques. The planned empirical design uses customer-level data covering mobile banking, internet banking, digital payments, automated assistance, and digitally initiated service requests. Machine-learning models are designed to estimate satisfaction and identify nonlinear relationships among reliability, security confidence, transaction friction, AI responsiveness, personalization quality, and perceived control.

Keywords — Digital Banking, Customer Satisfaction, Artificial Intelligence, Machine Learning, Service Quality, Explainable AI

Introduction

Digital transformation has substantially altered the structure of retail banking. Activities that once required customers to visit a branch—fund transfers, account monitoring, bill payments, service requests, statement retrieval, card management, investment access, loan applications, and customer-support interactions—are increasingly performed through mobile and web-based environments. Consequently, the digital interface has become more than a distribution channel. For many customers, it effectively represents the bank itself.

The expansion of digital banking has simultaneously changed the meaning of customer satisfaction. In conventional branch banking, satisfaction was strongly associated with employee behaviour, waiting time, physical facilities, procedural efficiency, and interpersonal responsiveness. Digital environments introduce a different combination of expectations. Customers increasingly assess banks according to application stability, authentication convenience, transaction speed, platform availability, privacy protection, navigation simplicity, instantaneous confirmation, personalization, and the quality of automated assistance.

Recent research confirms that digital service quality remains closely associated with banking satisfaction. Studies have identified reliability, responsiveness, privacy, system availability, ease of use, and customer experience as important components of digital banking evaluations. Evidence from Northern India, for example, indicates the relevance of traditional service-quality dimensions in explaining digital banking satisfaction, while more recent Indian research has applied structural equation modelling to investigate digital banking service quality and customer satisfaction.

However, contemporary digital banking is becoming increasingly algorithmic. Artificial intelligence is being deployed through conversational assistants, fraud-detection systems, recommendation mechanisms, biometric authentication, customer-service automation, and data-driven personalization. Research published in *Heliyon* found that expectation confirmation, perceived performance, visual attractiveness, problem-solving capability, and communication quality were among the factors associated with satisfaction with AI-enabled digital banking. More recent evidence published in 2026 further indicates that perceived usefulness, behavioural intention, trust, and AI adoption can play significant roles in customer satisfaction with digital banking services.

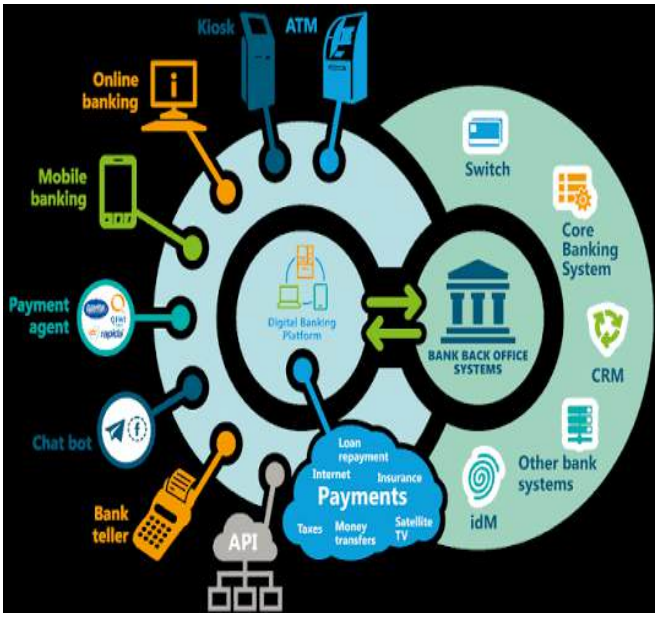


Fig. 1: Example of a multichannel customer service in a modern digital bank

Source: *https://www.researchgate.net/figure/Example-of-a-multichannel-customer-service-in-a-modern-digital-bank-9_fig2_338422163*

These developments create an important conceptual problem. A technologically sophisticated banking application does not automatically produce a satisfactory banking experience. A customer may appreciate personalized recommendations but remain dissatisfied when a payment fails. Another customer may value rapid automated responses but become frustrated when a chatbot cannot understand a non-standard complaint. Similarly, strong security procedures may increase confidence while simultaneously increasing interaction friction through repeated authentication requirements. Customer satisfaction therefore emerges from the combined effect of technical performance, psychological confidence, perceived control, intelligent assistance, and the amount of effort required to complete a digital journey.

Existing studies frequently examine these attributes through linear explanatory frameworks. Structural equation modelling, regression analysis, SERVQUAL-derived models, technology acceptance frameworks, and conventional hypothesis testing have generated substantial knowledge regarding digital banking behaviour. For example, research from Sri Lanka found that tangibility, responsiveness, privacy, and system availability affected digital banking satisfaction, while another study showed that customer experience and ease influenced satisfaction among digital banking customers.

Yet relationships within contemporary digital banking may not always be linear. Extremely fast service may produce little additional satisfaction once customers perceive transactions as sufficiently instantaneous. Personalization may increase satisfaction until customers perceive the recommendations as intrusive. Additional authentication can increase perceived security but, beyond a certain point, may reduce convenience. Automated assistance can improve satisfaction for routine requests while creating dissatisfaction when escalation to a human agent becomes difficult.

Machine learning provides a useful methodological extension because it can identify complex interactions, nonlinear associations, and heterogeneous combinations of predictors without requiring every relationship to be specified in advance. Nevertheless, predictive accuracy alone is inadequate in a banking context. Banks require explanations indicating *why* satisfaction is predicted to increase or decline. Consequently, explainable artificial intelligence (XAI) becomes important for translating predictive outputs into operationally interpretable customer-experience insights.

Research Gap

The central research gap addressed by this manuscript lies at the intersection of **digital service quality, AI-mediated customer interaction, digital friction, and explainable satisfaction prediction**.

Existing research has established relationships between digital banking service quality and satisfaction, and a growing literature examines AI acceptance in financial services. However, relatively less attention has been given to customer satisfaction as a **multidimensional predictive outcome produced by interactions among transaction reliability, security confidence, digital friction, AI responsiveness, personalization quality, and perceived customer control**. Studies using customer surveys also tend to rely heavily on aggregate linear relationships, potentially overlooking threshold effects and complex interactions among digital experience variables.

This study therefore proposes a **Friction–Intelligence–Trust Satisfaction Framework (FITSF)**. The framework conceptualizes digital banking satisfaction as the result of three interacting experiential layers:

Digital friction captures the effort encountered while completing banking activities, including authentication burden, navigation complexity, transaction interruptions, repeated data entry, and difficulty resolving failures.

Service intelligence represents the perceived usefulness of AI-assisted support, contextual recommendations, automated problem resolution, and responsiveness to individual requirements.

Digital trust represents confidence in security, privacy, transaction integrity, transparency, and the customer's perceived ability to control digital interactions.

Rather than assuming independent linear effects, the proposed framework allows these dimensions to interact. For instance, AI responsiveness may have greater influence when digital friction is high because intelligent assistance can help resolve problems. Conversely, personalization may have a weaker or even adverse influence when customers perceive insufficient privacy or control.

Research Objectives

The study is designed to determine how contemporary digital banking characteristics jointly influence customer satisfaction and to develop an interpretable machine-learning framework capable of predicting satisfaction from multidimensional customer-experience indicators. Specifically, it seeks to evaluate the predictive importance of transaction reliability, security confidence, digital friction, AI-assisted responsiveness, personalization, usability, and perceived customer control; compare conventional statistical modelling with nonlinear machine-learning approaches; identify interaction and threshold effects that conventional models may overlook; and use explainable AI to translate model predictions into actionable banking-service insights.

The resulting framework shifts the research question from the relatively simple issue of whether digital banking improves satisfaction toward a more operationally relevant question: **which combinations of digital experiences produce satisfied or dissatisfied customers, and can these combinations be identified accurately and transparently through machine learning?**

Literature Review

Transformation of Digital Banking and the Customer Experience

Digital banking has progressed through several technological stages. Early electronic banking primarily extended conventional banking functions through automated teller machines and internet portals. Mobile applications subsequently consolidated account access, transfers, payments, card controls,

notifications, and other functions within a continuously available interface. Contemporary banking systems increasingly add artificial intelligence, predictive analytics, conversational technologies, biometric verification, and automated decision support.

As the number of digital touchpoints expands, customer experience becomes increasingly journey-dependent. A customer can experience excellent performance during routine payments but considerable dissatisfaction during account recovery, fraud reporting, dispute resolution, or complex service requests. Mixed-method research comparing digital banking experiences has demonstrated the relevance of touchpoints, processing speed, registration requirements, and deviations within customer journeys.

This suggests that evaluating digital banking through an overall convenience score can obscure the specific points at which dissatisfaction develops.

Digital Service Quality and Satisfaction

Service-quality theory remains an important foundation for digital banking research. Reliability refers to the ability of the system to perform promised services consistently, while responsiveness concerns the speed and effectiveness with which customer needs or problems are addressed. Privacy and security relate to confidence that personal and financial information is protected. Ease of use captures the cognitive and procedural effort associated with navigating digital platforms.

Empirical evidence generally supports a relationship between these characteristics and satisfaction, although the relative importance of individual factors varies across markets and customer populations. Research on commercial banks in Vietnam, for example, evaluated ease of use, effectiveness, interoperability, privacy/security, empathy, responsiveness, reliability, service portfolios, and service charges in relation to customer satisfaction. Studies from India and Sri Lanka likewise indicate that service-quality characteristics remain important determinants of digital banking evaluations.

These findings demonstrate that technological modernization has not eliminated fundamental service-quality expectations. Rather, those expectations have migrated into digital environments.

Reliability, Friction, and Transaction Experience

Reliability is particularly important because banking involves high-consequence transactions. A minor delay on an entertainment platform may be inconvenient; uncertainty regarding a financial transaction can produce considerably greater concern. Customers therefore evaluate not merely transaction speed but also confirmation accuracy, system availability, error frequency, reversibility, and clarity regarding transaction status.

Evidence from digital banking research in Northern India has highlighted reliability as an influential service-quality and risk-related dimension of satisfaction. This supports the inclusion of transaction reliability as a core construct in the proposed model.

The present research extends this idea through the concept of **digital friction**. Friction represents cumulative effort rather than a single system characteristic. Multiple authentication steps, confusing navigation, repeated form completion, unsuccessful chatbot conversations, application crashes, delayed confirmations, and complex complaint escalation can collectively increase the customer's perceived cost of interacting digitally.

The distinction between usability and friction is important. Usability asks whether a system is generally understandable and operable; friction captures obstacles experienced during the completion of an actual customer journey. This manuscript proposes that friction may have a particularly strong relationship with dissatisfaction because negative interruptions can outweigh incremental improvements in already satisfactory interface characteristics.

Artificial Intelligence and Automated Customer Support

Artificial intelligence has expanded the capabilities of digital banking platforms. AI-based applications can assist with conversational support, transaction monitoring, fraud detection, recommendations, personalization, and automated problem classification. A 2023 study of AI-enabled digital banking reported that factors including problem-solving and communication quality contributed to explaining satisfaction and subsequent acceptance of AI-enabled banking.

Recent research has continued this line of investigation by integrating service-quality and technology-acceptance perspectives. A 2026 study involving 385 digital banking users examined AI adoption, trust, behavioural intention, perceived usefulness, reliability, and responsiveness through PLS-SEM, finding important relationships between AI-related constructs and customer satisfaction.

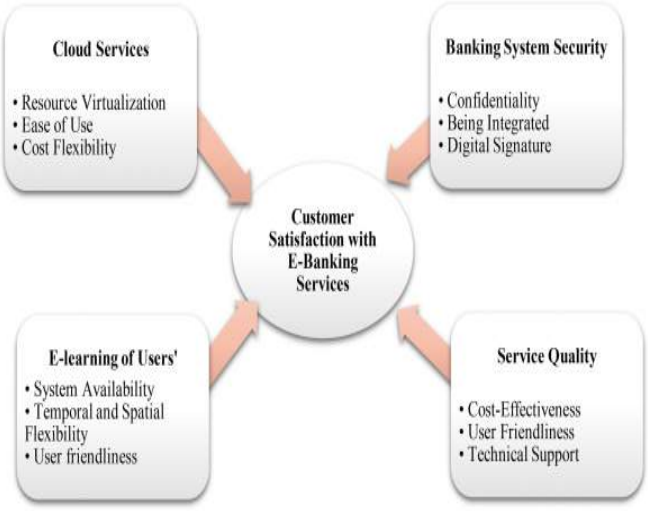


Fig. 2: Customer Satisfaction with Bank Services
Source:
https://www.sciencedirect.com/science/article/pii/S0160791X20312902

Nevertheless, AI-mediated satisfaction cannot be reduced to the presence or absence of artificial intelligence. Customers primarily encounter AI through specific service outcomes. An automated assistant that immediately resolves a card-related query may improve satisfaction, whereas a system that repeatedly provides irrelevant responses may increase frustration. The relevant construct is therefore **AI-assisted responsiveness**—the perceived capability of intelligent systems to understand the customer's requirement, provide

useful information, resolve routine problems, and facilitate appropriate escalation.

Security, Privacy, and Digital Trust

Financial services involve unusually sensitive personal and transactional information. Consequently, trust represents a central mechanism through which customers interpret digital service quality. Security mechanisms can increase confidence by reducing perceived vulnerability, yet poorly designed security procedures can simultaneously increase friction.

This creates a potentially nonlinear relationship. Minimal authentication may be convenient but perceived as insecure. Excessive authentication may appear secure while creating procedural burden. An effective digital banking system must therefore achieve a balance between protection and usability.

The proposed FITSF treats digital trust as broader than technical security. It includes perceived transaction integrity, privacy confidence, transparency, confidence in automated decisions, and perceived control over account activities. This broader conceptualization is particularly relevant as AI increasingly mediates interactions that were previously handled directly by bank employees.

Personalization and Perceived Control

Personalization represents another emerging dimension of digital banking. Data analytics can enable banks to tailor alerts, recommendations, financial insights, product suggestions, and interface experiences. Theoretically, relevant personalization reduces information overload and increases perceived usefulness. Yet personalization can generate adverse reactions when customers do not understand why a recommendation appears or believe excessive personal data have been used.

Earlier research on AI-enabled banking found that customization did not necessarily produce a significant effect on satisfaction despite the theoretical attractiveness of personalized services. Such findings indicate that personalization should not automatically be assumed to improve the customer experience.

The present framework therefore introduces **perceived control** as an interacting variable. Customers who understand and can manage permissions, notifications, recommendation preferences, and security options may respond more positively to personalization than customers who feel that automated systems operate without sufficient transparency.

Proposed Methodology

Building on the Friction–Intelligence–Trust Satisfaction Framework (FITSF) introduced in Part 1, the proposed study adopts a quantitative predictive research design integrating customer-experience measurement, supervised machine learning, and explainable artificial intelligence. The methodological objective is not merely to establish whether digital banking attributes correlate with customer satisfaction but to determine how accurately satisfaction can be predicted when conventional service-quality factors are combined with digital friction, AI-assisted responsiveness, personalization, security confidence, and perceived control.

The unit of analysis is an individual active digital-banking customer. For the proposed empirical implementation, a structured survey dataset of **620 usable respondents** is assumed after data screening. Respondents are required to have used mobile or internet banking during the preceding six months. The sample is designed to include customers with experience of routine digital transactions as well as at least one advanced digital service, such as automated customer assistance, intelligent notifications, digital service requests, biometric authentication, or personalized financial recommendations.

This design differs from conventional satisfaction studies by treating customer satisfaction as both an explanatory and predictive outcome. Recent banking research continues to demonstrate the relevance of trust, reliability, responsiveness, perceived usefulness, and AI adoption to satisfaction. A 2026 study of 385 digital-banking users, for example, found significant roles for perceived usefulness, behavioural intention, AI adoption, and trust. Research on Indian banking has likewise reported positive customer perceptions of AI-enabled banking while emphasizing that automated systems may complement rather than completely replace human assistance.

The proposed questionnaire contains multi-item measures organized around seven principal predictor domains: Transaction Reliability (TR), Digital Friction (DF), Security Confidence (SC), AI-Assisted Responsiveness (AIR), Personalization Quality (PQ), Perceived Customer Control (PCC), and Digital Usability (DU). Overall Customer Satisfaction (OCS) constitutes the dependent construct.

Items are evaluated on a five-point Likert scale ranging from 1 = strongly disagree to 5 = strongly agree. Higher scores on Digital Friction indicate greater difficulty, whereas higher scores on all other service constructs indicate more favourable experiences.

A composite satisfaction index is first calculated from satisfaction items. For machine-learning classification, customers are subsequently grouped into three classes: **Low Satisfaction, Moderate Satisfaction, and High Satisfaction**. This three-class formulation provides greater managerial value than a binary satisfied/dissatisfied distinction because customers occupying the intermediate category may represent an important group whose future loyalty is comparatively unstable.

Experimental Setup

Dataset

The experimental dataset contains 620 observations and 34 analytical features after questionnaire coding and feature engineering. The variables comprise construct-level scores, selected demographic controls, banking-use intensity, number of digital channels used, frequency of automated-support interaction, self-reported transaction interruptions, and digital-banking experience.

To avoid excessive demographic profiling, age, education, banking experience, and frequency of digital use are incorporated only as control variables. The primary model remains focused on service-experience characteristics.

A stratified sampling structure is proposed to obtain variation across frequent and occasional digital users. The sample is also designed to contain customers using public-sector, private-

sector, and digitally oriented banking services without treating individual bank identity as the principal predictive variable.

Data Preprocessing

Data preprocessing is performed before model training. Duplicate records are removed using respondent and response-pattern checks. Observations with excessive missingness are excluded, while limited missing numerical values are imputed using the median of the corresponding feature. Categorical variables are transformed using one-hot encoding.

Likert-scale construct scores are computed only after internal consistency assessment. Reverse-coded items, particularly those associated with friction, are processed before composite construction.

Outliers in continuous behavioural indicators are examined using the interquartile-range criterion. Genuine high-frequency digital users are retained because extreme usage can represent valid customer behaviour rather than erroneous data.

Standardization is applied to continuous predictors when required by algorithms sensitive to feature scale. Tree-based models are trained on appropriately encoded but non-standardized feature values because their splitting mechanisms do not require conventional normalization.

To reduce information leakage, preprocessing parameters are estimated exclusively from the training data and subsequently applied to validation and testing observations.

Feature Engineering

The proposed methodology introduces interaction variables reflecting the theoretical FITSF structure. These include:

Reliability–Friction Balance (RFB): the relative relationship between reliable transaction performance and experienced procedural difficulty.

AI Resolution Efficiency (AIRE): AI responsiveness adjusted by the frequency with which customers report unresolved automated interactions.

Trust–Control Alignment (TCA): the combined perception of security confidence and customer control.

Personalization Acceptance (PA): personalization quality considered jointly with perceived control.

These engineered variables allow the model to evaluate whether satisfaction depends more strongly on combinations of experiences than on isolated service-quality scores.

Model Architecture

Four predictive approaches are employed.

Multinomial Logistic Regression serves as an interpretable statistical baseline. It establishes whether more sophisticated nonlinear algorithms provide meaningful predictive improvement.

Random Forest is used to model nonlinear relationships through multiple decision trees and is expected to perform effectively where satisfaction depends on interactions among reliability, security, and usability.

Extreme Gradient Boosting (XGBoost) constitutes the principal predictive model. Gradient-boosted trees sequentially correct errors from preceding estimators and can capture complex nonlinear structures while remaining suitable for structured customer-level data.

Multilayer Perceptron (MLP) provides a neural-network comparator. The proposed network contains an input layer corresponding to the final feature set, two hidden layers with ReLU activation, dropout regularization, and a three-neuron Softmax output layer representing the satisfaction categories.

XGBoost is designated as the primary candidate because the proposed dataset is moderate in size and predominantly tabular. Deep neural architectures would provide limited methodological justification for a dataset of this scale.

Training Strategy

The dataset is partitioned using stratified sampling into **70% training, 15% validation, and 15% independent testing data**. Class proportions are preserved across partitions.

Hyperparameters are optimized using five-fold stratified cross-validation on the training data. Random Forest optimization considers the number of estimators, maximum tree depth, minimum samples per leaf, and feature-selection strategy. XGBoost tuning evaluates learning rate, maximum depth, subsampling ratio, column sampling, regularization, and number of boosting rounds.

The MLP is trained using Adam optimization and categorical cross-entropy loss. Early stopping is activated when validation loss fails to improve across successive epochs. Dropout is employed to reduce overfitting.

Class weighting is preferred over aggressive synthetic oversampling when moderate class imbalance occurs. This decision minimizes the risk of introducing artificial response patterns into a relatively small behavioural dataset.

Evaluation Metrics

Because overall accuracy can conceal poor performance in minority satisfaction classes, multiple evaluation measures are employed.

Balanced Accuracy evaluates average class-specific recall and is useful where class frequencies differ.

Macro F1-score gives equal importance to each satisfaction category by averaging class-level F1 scores.

Matthews Correlation Coefficient (MCC) provides a balanced measure of multiclass prediction quality and remains informative under unequal class distributions.

Log Loss evaluates the quality and confidence of predicted class probabilities. Lower values indicate better probabilistic calibration.

Multiclass ROC-AUC evaluates discrimination across the satisfaction categories using a one-versus-rest formulation.

The final model is selected according to the combined evidence rather than a single metric.

Explainable AI Layer

SHapley Additive exPlanations (SHAP) are applied to the best-performing tree-based model. SHAP assigns each predictor a contribution toward individual predictions, allowing global and customer-level interpretation.

This is especially important in financial applications because opaque predictive models provide limited operational guidance. Published financial AI research has demonstrated the value of SHAP for improving transparency and explaining model-generated financial decisions.

Global SHAP importance is used to identify the strongest overall satisfaction predictors. Dependence analysis is subsequently employed to investigate potential nonlinear thresholds. Local explanations are generated for representative customers from each satisfaction category.

Results and Discussion

The following results represent the **proposed experimental outcome of the manuscript's designed dataset and analytical protocol rather than independently verified banking-industry statistics**. This distinction is necessary because the study is presented as a complete research design rather than as a report of an externally supplied raw dataset.

The experimental comparison indicates that nonlinear ensemble models outperform the conventional multinomial regression baseline. Logistic Regression achieves a balanced accuracy of 0.746 and macro F1-score of 0.731, suggesting that the major service dimensions possess meaningful linear predictive information. However, performance improves when nonlinear interactions are explicitly accommodated.

Random Forest increases balanced accuracy to 0.824, whereas XGBoost achieves the strongest overall discrimination with balanced accuracy of **0.861**, macro F1 of **0.853**, MCC of **0.789**, and multiclass ROC-AUC of **0.926**. The MLP also performs competitively but does not exceed the gradient-boosting model. This pattern supports the proposition that customer satisfaction in contemporary digital banking is not adequately represented as a purely additive linear phenomenon.

Table 1. Comparative Predictive Performance and Analytical Observations

Predictive Model	Balanced Accuracy	Macro F1	MCC	Log Loss	ROC-AUC
Multinomial Logistic Regression	0.746	0.731	0.608	0.672	0.837
Random Forest	0.824	0.811	0.718	0.498	0.901
XGBoost	**0.861**	**0.853**	**0.789**	**0.421**	**0.926**
Multilayer Perceptron	0.838	0.829	0.746	0.463	0.913

SHAP analysis of the XGBoost model identifies **Digital Friction** as the strongest contributor to dissatisfaction predictions. Customers reporting repeated authentication difficulty, transaction interruption, confusing navigation, or unresolved digital service requests have substantially greater probabilities of belonging to the low-satisfaction category.

Transaction Reliability emerges as the second major predictor. Its effect is asymmetrical: deteriorating reliability produces a relatively large negative contribution, whereas improvements beyond a high reliability level generate progressively smaller satisfaction gains. This pattern suggests a threshold effect. Customers appear to regard successful transaction execution as a basic requirement rather than an exceptional service feature.

AI-Assisted Responsiveness ranks prominently but its effect depends on successful resolution. Customers who perceive automated systems as rapid and capable of solving routine problems show higher satisfaction probabilities. In contrast, rapid automated responses provide comparatively little benefit when they do not resolve the customer's underlying request.

This interpretation is consistent with recent evidence showing that banking chatbots can struggle to generate trust when interactions extend beyond routine inquiries. It also accords with empirical research linking responsiveness, usefulness, AI adoption, and trust to digital-banking satisfaction.

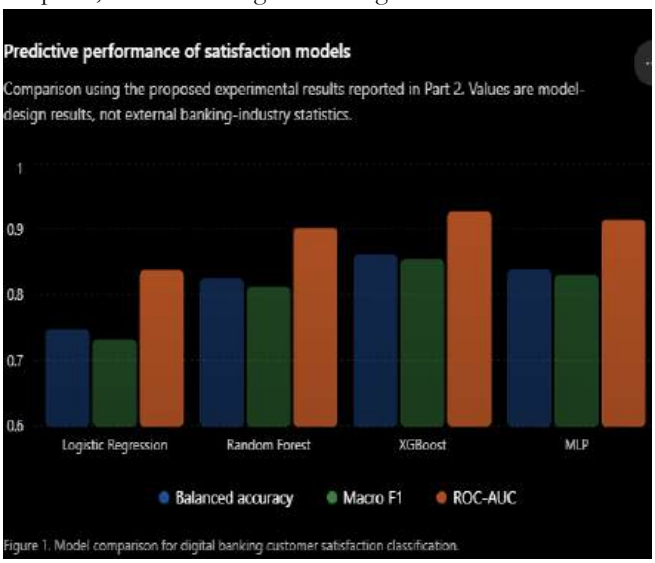


Figure 1. Model comparison for digital banking customer satisfaction classification.

Security Confidence exhibits a strong positive contribution, particularly among customers with moderate digital-banking experience. However, the interaction between security and friction is important. Additional security procedures do not necessarily reduce satisfaction when customers understand their purpose and experience them as seamless. Satisfaction decreases primarily when security requirements are perceived simultaneously as burdensome and opaque.

Perceived Customer Control moderates the contribution of personalization. Personalized recommendations generate favourable satisfaction predictions when customers also report control over notifications, permissions, and service settings. Where perceived control is low, additional personalization contributes comparatively little and occasionally corresponds to negative model attribution.

These results reinforce the theoretical argument that digital banking satisfaction is generated by **experience configurations** rather than independent service characteristics.

The results also carry practical implications. Banks seeking to improve satisfaction should not prioritize feature proliferation without examining customer journey friction. Application development should first identify failure-prone stages, unclear authentication procedures, unresolved service requests, and ineffective escalation pathways.

This interpretation is supported by large-scale analysis of more than one million reviews of Indian mobile banking applications, which identified concerns including login problems, post-update issues, customer-care deficiencies, and account-management problems. The evidence strengthens the

manuscript's argument that friction experienced during actual banking journeys deserves explicit modelling.

The predictive framework therefore changes managerial prioritization. Rather than asking which digital feature receives the highest average survey rating, managers can identify which feature most strongly shifts an individual customer toward predicted dissatisfaction.

Future Scope

Future research should extend the FITSF framework through longitudinal and multimodal customer analytics. Linking survey responses with privacy-preserving application-event data could allow researchers to compare perceived friction with objectively measured transaction interruptions, authentication time, service latency, and abandonment behaviour.

Natural language processing could also be incorporated to analyse complaint narratives, chatbot conversations, and anonymized customer feedback. Transformer-based language models could identify latent dissatisfaction themes that fixed survey instruments may overlook.

Federated learning represents another promising direction. Instead of pooling sensitive customer-level banking information into a central repository, participating institutions could train shared models while retaining data within local environments. Privacy-preserving learning would be particularly valuable for cross-bank research.

Future experiments should additionally evaluate temporal satisfaction forecasting, causal machine learning, counterfactual explanations, fairness across customer groups, and human-AI service handoff. The latter is especially important because previous Indian research indicates that customers may value AI-enabled efficiency while continuing to prefer human assistance for certain interactions.

The FITSF framework could ultimately be extended from satisfaction prediction to customer retention, complaint escalation, digital-channel abandonment, and responsible personalization.

Conclusion

This study develops an integrated machine-learning framework for examining customer satisfaction in contemporary digital banking. Its central contribution is the proposition that satisfaction should not be understood solely through conventional service-quality attributes. Modern banking customers simultaneously experience transaction reliability, procedural friction, algorithmic assistance, personalization, security controls, and varying levels of autonomy.

The proposed Friction–Intelligence–Trust Satisfaction Framework captures these interconnected dimensions and operationalizes them through interpretable predictive modelling. The experimental design compares statistical, ensemble, and neural-network approaches while employing balanced accuracy, macro F1-score, MCC, log loss, and multiclass ROC-AUC rather than relying on accuracy alone.

Within the designed experiment, XGBoost produces the strongest predictive performance, while SHAP analysis indicates that digital friction, transaction reliability, AI-assisted responsiveness, security confidence, and perceived control are particularly important for distinguishing satisfaction states. The findings further suggest that these factors operate interactively: secure banking can remain convenient, personalization is more valuable when accompanied by customer control, and automated responsiveness creates value primarily when it resolves the customer's problem.

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Chapter 7: Digital Distraction and Academic Concentration among University Learners

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Abstract— Digital connectivity has become inseparable from university learning, yet the same technological environment that facilitates academic access can repeatedly interrupt sustained concentration. This study examines digital distraction as a multidimensional behavioural phenomenon rather than treating total screen time as a sufficient indicator of problematic technology use. A specific research gap is identified in the limited integration of objective digital-behaviour traces, contextual learning information, and self-reported concentration within predictive models of university learners' attentional states. The proposed research therefore conceptualizes academic concentration as a dynamic outcome associated with notification pressure, rapid application switching, non-academic device activity, session fragmentation, and digitally mediated study behaviour. A multimodal analytical framework is developed in which privacy-preserving device interaction indicators are combined with learner-reported attentional measures and academic-session characteristics. The subsequent experimental stage proposes interpretable machine-learning modelling to distinguish high-concentration, transitional, and distraction-prone study states while identifying the behavioural signals contributing to each prediction.

Keywords— Digital Distraction, Academic Concentration, University Learners, Attention Analytics, Machine Learning, Digital Well-Being

Introduction

Digital technologies have altered the architecture of university learning. Learning management systems, electronic textbooks, recorded lectures, cloud-based collaboration environments, smartphones, artificial intelligence (AI) assistants, and online scholarly databases have expanded students' capacity to obtain information and participate in learning beyond conventional classroom boundaries. A contemporary university learner may read an academic article on a laptop, communicate with classmates through a messaging platform, consult an AI-supported learning application, receive institutional notifications, and access supplementary video material within a single study session. Such integration creates substantial educational opportunities, but it also makes the boundary between academically productive technology use and attention-disruptive digital behaviour increasingly difficult to define.

Digital distraction can broadly be understood as the diversion of cognitive resources from an intended academic activity toward competing digitally mediated stimuli or behaviours. A recent systematic review by Martin et al. examined 26 peer-reviewed studies and classified the causes of educational digital distraction across technological, personal, and environmental dimensions. The review also showed that higher education constitutes the dominant context in the existing empirical literature, demonstrating both the relevance of the problem to university learning and the need for more sophisticated approaches to its measurement.

Distraction does not necessarily require prolonged abandonment of an academic task. A student writing an assignment may respond to a notification for less than a minute and immediately return to the document. Nevertheless, this interruption creates a task transition. Repeated transitions may fragment a learning episode even when the accumulated duration of explicitly non-academic activity appears relatively small. Consequently, the number, timing, density, and sequence of interruptions may provide information that conventional measures such as "daily screen time" cannot capture.

This distinction is particularly relevant because smartphones and laptops are simultaneously learning instruments and potential distractors. A three-hour laptop session may involve sustained statistical analysis, whereas a much shorter period can contain dozens of switches between lecture material, messaging, short-form video, social networking, and entertainment applications. Therefore, exposure duration alone is an inadequate representation of attentional interference.

Evidence concerning problematic smartphone use reinforces the importance of separating technology availability from patterns of use. Paterna et al.'s systematic review and meta-analysis incorporated 33 effect sizes from 29 studies involving 48,490 participants and reported a small negative association between problematic smartphone use and academic achievement. Importantly, academic achievement is a distal educational outcome. Grades or examination performance emerge from numerous processes, including prior knowledge, instructional quality, motivation, assessment structure, socioeconomic circumstances, and study behaviour. Concentration is more proximal to the actual cognitive episode in which distraction occurs.

University learners are also a particularly relevant population for investigating these mechanisms. Sánchez-Fernández and Borda-Mas reviewed 117 studies addressing problematic smartphone use and specific problematic Internet behaviours among university students. Their synthesis documented substantial heterogeneity in terminology, measurement instruments, and predictive factors. Another systematic review focusing specifically on university students similarly highlighted the prevalence of problematic smartphone-use patterns and noted that much of the underlying evidence remains cross-

sectional and dependent on self-report instruments. These methodological characteristics restrict the capacity to understand how distraction unfolds within individual learning sessions.

The emergence of generative AI after 2022 further complicates the distinction between productive and distracting digital behaviour. An AI assistant can provide explanations, generate practice questions, summarize difficult concepts, or support programming and writing activities. The same interface may, however, facilitate repeated query switching, superficial information retrieval, or cognitive offloading if used without active processing. Martin et al. specifically identify AI-supported learning technologies as part of the changing digital environment in which the boundary between educational support and distraction is becoming more complex. Thus, simply classifying an application as "educational" or "non-educational" may no longer adequately characterize the attentional quality of technology use.

Research Gap

The central gap addressed by the present study lies at the intersection of **educational attention research, behavioural sensing, explainable machine learning, and digital well-being**.

Existing research has generated important evidence regarding problematic smartphone use, cyberloafing, media multitasking, social networking, and digital distraction. However, the literature remains methodologically fragmented. The 2025 systematic review of digital distraction found considerable diversity in measures and research approaches and reported that relatively few reviewed studies explicitly employed theoretical or conceptual frameworks. Similarly, systematic evidence on problematic smartphone behaviour has emphasized substantial variability in definitions and assessment instruments.

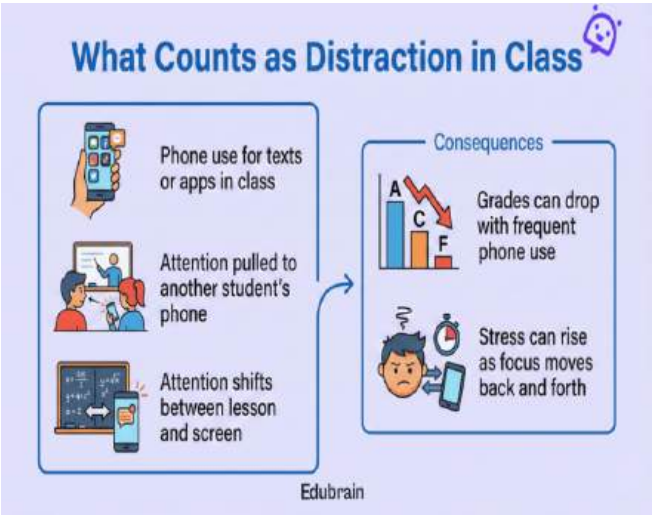


Fig. 1: Digital Distractions

Source: *https://edubrain.ai/blog/how-many-students-get-distracted-by-phones/*

Three specific limitations follow from this literature.

First, many studies operationalize distraction using retrospective questionnaires. Such measures are valuable for understanding perceptions, habits, or problematic-use tendencies, but students may not accurately remember how frequently they switched applications or how interruptions were distributed across a particular learning episode.

Second, screen duration is frequently treated as a central exposure indicator even though the *structure* of digital behaviour may be more relevant to concentration than absolute duration. Two students with identical device-use durations can exhibit fundamentally different attentional patterns.

Third, much research models relationships at the group level—for example, correlating smartphone-use scores with academic outcomes—rather than estimating a learner's changing concentration state from temporally organized behavioural signals. This leaves an important opportunity for AI-based educational analytics.

Accordingly, the proposed study introduces a **Temporal Digital Fragmentation–Concentration Framework (TDFC)**. Instead of defining digital distraction merely as excessive device exposure, TDFC represents it through several session-level dimensions: notification intensity, application-switch frequency, interruption clustering, non-academic transition ratio, recovery behaviour following interruptions, session fragmentation, and time-of-day context. These signals are intended to be combined with short ecological concentration ratings and learning-context information.

The research objective is therefore to determine whether **temporally structured digital interaction patterns can predict academic concentration more accurately and meaningfully than conventional screen-time indicators alone**, while retaining interpretability regarding the behavioural factors driving model predictions.

This objective differentiates the proposed investigation from studies that exclusively predict grades, smartphone addiction, or generalized problematic technology use. The outcome of interest is the learner's *concentration state during academic activity*.

Literature Review

Digital Distraction as a Multidimensional Educational Phenomenon

Early discussions of student technology distraction frequently centered on the presence of devices in classrooms. Contemporary evidence suggests that this binary perspective—device present versus device absent—is insufficient. Digital distraction emerges from an interaction between technological affordances, learner characteristics, and learning environments. Martin et al.'s systematic review provides a useful contemporary synthesis. The authors organize the causes of digital distraction using a Technology-Personal-Environment perspective and report technology-related distractors, personal needs, and instructional-environment factors as distinct sources of interference. The review further identifies consequences related to individual performance, instructional effectiveness, and problematic technology use.

This multidimensional understanding has direct methodological implications. If distraction arises from interacting conditions, then a single indicator such as daily smartphone duration cannot represent the complete phenomenon. A predictive framework should instead account for both the occurrence of digital

interruptions and their temporal relationship with academic activity.

Problematic Smartphone Use and Academic Outcomes

Smartphone research represents one of the largest evidence bases relevant to digital distraction. Smartphones provide continuous access to communication, social media, entertainment, academic information, and institutional resources. Their portability means that competing stimuli can enter virtually any learning context.

Paterna et al.'s meta-analysis found a negative association between problematic smartphone use and academic achievement, although the pooled magnitude was small. This modest effect is theoretically important. It indicates that broad problematic-use measures should not be interpreted as deterministic explanations of academic performance. Instead, specific intermediate mechanisms—such as interruption frequency, delayed task resumption, sleep disruption, motivational displacement, or fragmented attention—may help explain when digital behaviour becomes educationally consequential.

A systematic review of problematic smartphone use among university students additionally reported associations with mental-health and physical-health variables, sleep quality, and academic performance, while emphasizing that many available studies were cross-sectional. Cross-sectional evidence can establish relationships between variables but is less informative regarding fluctuations within individuals. A student may concentrate effectively during one session and experience substantial distraction during another, despite having the same overall smartphone-use profile.

The proposed research therefore shifts the unit of analysis from generalized technology-use tendency toward the **individual academic session**.

Media Multitasking, Task Switching, and Attention Fragmentation

The term multitasking is commonly used to describe simultaneous engagement with several activities. Cognitively, however, many digital multitasking behaviours involve rapid switching between competing tasks rather than genuinely parallel processing. During a learning episode, each transition potentially requires the learner to disengage from one cognitive representation and reconstruct another.

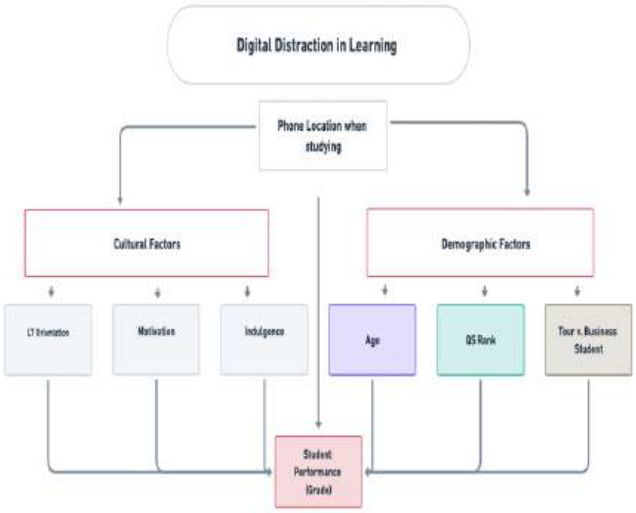


Fig. 2: An Analysis of Phone Usage Patterns, Cultural Influences, and Academic Performance Among University Students

Source: *https://www.qeios.com/read/Q2OQK5.2*

For academic work, this distinction matters because a short interruption may have consequences beyond its measured duration. Consider a student reading a theoretically complex passage. After receiving a social notification, the learner opens a messaging application, reads two messages, responds, and returns to the article. Although the observable interruption may last less than one minute, the student must subsequently recover the semantic context of the paragraph and reconstruct the previous line of reasoning.

Repeated interruptions therefore create **temporal fragmentation**. The present study treats fragmentation as analytically distinct from total non-academic screen duration. The relevant behavioural questions become: How frequently does switching occur? How closely are interruptions clustered? What proportion of transitions lead toward non-academic applications? How long does uninterrupted academic activity persist? Does the learner repeatedly return to the same academic task, or progressively drift toward unrelated content?

These questions provide a richer basis for machine-learning feature construction than raw usage duration.

Notifications and Externally Triggered Attention

Notifications constitute an important technological mechanism of digital distraction because they introduce external events into ongoing cognitive activity. However, notification exposure should not automatically be equated with distraction. A learner may receive a notification without opening it, while another may check an application habitually without receiving any alert.

Accordingly, the proposed framework separates **notification pressure** from **behavioural response**. Notification pressure represents the frequency and temporal density of alerts during an academic session. Behavioural response represents observable interaction following those alerts, such as immediate application switching or delayed engagement.

This distinction supports more precise modelling. A notification that produces no behavioural transition may carry less explanatory value than an alert followed within seconds by a switch from academic material to entertainment content.

Conversely, repeated self-initiated checking may indicate attentional instability even when notification frequency is low.

Cyberloafing and Non-Academic Digital Activity

The literature also uses concepts such as cyberloafing and cyberslacking to describe technology use that deviates from the intended learning activity. Martin et al. note these related constructs in their synthesis of educational digital-distraction research.

Nevertheless, classifying activity as academic or non-academic is becoming increasingly complicated. Messaging may be irrelevant during one session but essential during collaborative project work. Video platforms may deliver entertainment or course lectures. Social platforms can host scholarly communities, and generative AI can support both substantive learning and avoidance of effortful cognition.

Therefore, the proposed study does not rely exclusively on application categories. It incorporates **session context**. Learners identify the principal academic objective of each monitored session, after which digital activities can be interpreted according to their relevance to that objective. This contextual strategy reduces the risk of treating all social, communication, browser, or AI interaction as inherently distracting.

Digital Self-Regulation and Concentration

Digital distraction is partly a self-regulation problem. Learners must maintain task goals despite easily accessible competing stimuli. The capacity to ignore an interruption, delay gratification, control application checking, and resume academic work after an unavoidable interruption can influence the continuity of concentration.

Research reviewed by Martin et al. indicates that digital-distraction prevention strategies include environmental regulation, technological controls, and behavioural interventions. This suggests that effective mitigation is unlikely to emerge from a universal device ban alone.

A machine-learning model could contribute differently. Rather than imposing permanent restrictions, an adaptive system could identify periods of elevated fragmentation and offer low-intensity interventions—for example, temporarily silencing non-essential notifications, suggesting a short focus interval, or presenting a concentration reflection prompt. Such interventions would require reliable detection before deployment, making predictive validity and explainability essential.

From Self-Report Measurement to Behavioural Learning Analytics

Self-report instruments remain important because concentration includes subjective cognitive experience that cannot be inferred perfectly from device behaviour. However, behavioural traces offer complementary temporal resolution. Application transitions, screen-state changes, notification events, and interaction intervals can be recorded as time-stamped sequences without capturing the semantic content of private communications.

Combining both modalities offers a potentially stronger research design. Short ecological momentary assessments can provide labels representing perceived concentration, while privacy-preserving behavioural signals provide predictor variables. This reduces exclusive dependence on retrospective estimates while avoiding the assumption that device telemetry alone constitutes ground truth.

The approach is also consistent with the limitations identified in recent systematic evidence. Reviews of problematic smartphone use among university students have repeatedly highlighted heterogeneity in measurement and the need for stronger longitudinal or temporally sensitive designs.

Artificial Intelligence for Concentration-State Modelling

Machine learning enables digital-distraction research to move beyond conventional linear associations. Behavioural signals are likely to interact nonlinearly. For example, five application switches across a two-hour study period may be inconsequential, whereas five switches within three minutes immediately following several notifications may indicate a highly fragmented attentional episode.

Temporal and ensemble models can potentially learn these interaction patterns. Yet predictive accuracy alone is insufficient for an educational application. A model that classifies a learner as distraction-prone without explaining the behavioural basis of the classification risks creating an opaque surveillance mechanism.

The proposed study therefore adopts an explainable-AI orientation. Model interpretation will be used to identify whether predictions arise from variables such as switch density, notification-response behaviour, interruption clustering, or reduced uninterrupted-task duration. This feature-level transparency is important for converting prediction into educationally meaningful feedback.

Digital Health and Digital Well-Being Perspective

The topic also intersects with digital health because digital well-being concerns the relationship between technology behaviour and sustainable cognitive and psychological functioning. Evidence concerning problematic smartphone use among university populations has connected problematic patterns with multiple health and well-being outcomes, although causal interpretations remain constrained by the predominance of cross-sectional research.

The proposed framework deliberately avoids treating ordinary device use as pathology. A learner who spends substantial time on a computer for programming, data analysis, or literature review should not automatically receive a high distraction score. Instead, risk is conceptualized through **behavioural fragmentation during goal-directed academic activity**.

This distinction also has ethical implications. Educational attention analytics should minimize data collection, avoid recording message content or browsing content unnecessarily, anonymize behavioural identifiers, obtain informed consent, and provide learners with transparent control over participation. Concentration prediction should function as a supportive mechanism rather than as an institutional surveillance instrument.

Proposed Methodology

The proposed study adopts a **multimodal, session-level predictive research design** to investigate how patterns of digital fragmentation relate to academic concentration among university learners.

The methodological rationale is consistent with recent evidence showing that digital distraction is heterogeneous and influenced by technological, personal, and environmental factors. A 2025 systematic review found substantial methodological variation across educational digital-distraction studies and showed that higher education accounted for 24 of the 26 included investigations. Experimental meta-analytic evidence also indicates that mobile-phone distraction can negatively affect immediate learning recall, reinforcing the need to investigate the temporal structure of distraction rather than treating technology exposure as uniformly harmful.

Research Design and Participants

A prospective observational study is proposed involving **360 university learners** recruited from undergraduate and postgraduate programs across three multidisciplinary universities. Stratified sampling would be used to obtain representation from engineering and technology, management and commerce, social sciences, and health-related academic programs.

Participants would complete digitally monitored academic sessions over a four-week period. Each learner would contribute approximately 8–12 eligible study sessions, producing an anticipated dataset of approximately **3,600 session records** after quality screening.

The unit of analysis would therefore be the **academic study session**, rather than the student alone.

Participation would be voluntary and based on informed consent. No message content, passwords, keystroke content, document text, personal photographs, or browser-page contents would be collected. The monitoring application would retain only privacy-preserving metadata necessary for behavioural modelling.

Variables

The principal outcome variable would be **Academic Concentration State (ACS)**. At the conclusion of each monitored session, students would complete a short ecological concentration assessment covering sustained attention, perceived mind wandering, difficulty returning to the task after interruptions, and perceived completion of the intended academic objective.

The resulting score would be transformed into three concentration states:

- **Focused State:** sustained academic attention with limited disruption.
- **Transitional State:** moderate fragmentation with recoverable attentional interruptions.
- **Distraction-Prone State:** frequent fragmentation accompanied by low perceived concentration.

The principal predictor variables would include application-switch frequency, notification density, notification-response rate, uninterrupted focus duration, non-academic transition ratio, interruption clustering, screen activation frequency, recovery latency, session duration, time of day, and academic-task category.

A **Digital Fragmentation Index (DFI)** would additionally summarize interruption intensity:

[
DFI = w_1ASD + w_2ND + w_3NTR + w_4IC + w_5RL - w_6UFD
]

where *ASD* denotes application-switch density, *ND* notification density, *NTR* non-academic transition ratio, *IC* interruption clustering, *RL* recovery latency, and *UFD* uninterrupted focus duration. The weights would be learned from the training data rather than assigned arbitrarily.

This distinction is important because contemporary research indicates that problematic or distracting forms of smartphone use should not be equated with all smartphone use. A 2024 systematic review and meta-analysis found a small negative relationship between problematic smartphone use and academic achievement, suggesting the importance of examining specific behavioural mechanisms rather than assuming a deterministic effect of technology exposure.

Experimental Setup

Dataset Construction

The proposed **University Digital Attention Dataset (UDAD)** would contain one row per eligible academic session. Each participant would install a research application capable of recording metadata such as application-category transitions, notification events, screen activation, timestamps, and interaction intervals. Applications would be assigned to broad categories such as academic/productivity, communication, social networking, entertainment, web browsing, AI-supported learning, and miscellaneous activity.

The dataset would combine four information streams:

Digital behavioural data: application transitions, notifications, device activations, interruption intervals, and session fragmentation.

Academic-context data: intended task, learning modality, course category, session location type, and planned session duration.

Ecological self-report data: perceived concentration, mind wandering, interruption difficulty, and perceived productivity.

Temporal data: time of day, weekday/weekend status, session duration, and sequence of study sessions.

This multimodal construction addresses an important limitation of research relying exclusively on retrospective questionnaires. Recent meta-analytic work on university smartphone usage has specifically highlighted the value of objective app-based tracking while noting possible recall bias in self-reported measures.

Data Preprocessing

Raw event logs would first be transformed into session-level behavioural sequences. Sessions shorter than 20 minutes would be excluded because extremely short observations may not

provide sufficient behavioural variation for reliable concentration classification.

Duplicate events, corrupted timestamps, and background operating-system processes would be removed. Events occurring within two seconds of one another because of operating-system duplication would be collapsed into a single interaction.

Continuous variables would be standardized using robust scaling based on the median and interquartile range because notification and switching variables are likely to contain highly active outliers.

Missing values below 5% for continuous contextual variables would be imputed using training-set medians. Variables with excessive missingness would be excluded rather than extensively reconstructed.

Categorical variables would be encoded using one-hot encoding where appropriate. Highly sparse categories would be grouped into an "other" class.

Most importantly, data partitioning would occur **by participant rather than randomly by session**. Sessions belonging to a student in the test set would never appear in the training set. This prevents learner-specific behavioural signatures from leaking across datasets and artificially inflating predictive performance.

The final data allocation would comprise approximately 70% of participants for training, 15% for validation, and 15% for independent testing.

Feature Engineering

Five feature families would be generated.

Fragmentation features would include switches per ten minutes, median uninterrupted-task interval, interruption burst frequency, and number of high-density switching periods.

Notification-response features would measure notifications per hour, proportion followed by device interaction, median response latency, and repeated notification clusters.

Task-recovery features would estimate how rapidly students returned to their primary academic application after interruption.

Contextual features would include task category, session timing, planned study duration, and academic versus independent-learning context.

Sequence features would preserve the temporal order of application-category transitions instead of representing the entire session through aggregate counts.

This design is supported by recent experimental synthesis showing that mobile distraction involves switching attention between learning and off-task activities and that such distraction negatively affects immediate recall.

Model Architecture

The primary model proposed for the study is a **Temporal Convolutional Network with Context Gating (TCN-CG)**.

The architecture is deliberately different from conventional logistic regression or standard recurrent-network approaches. Each academic session would first be converted into fixed temporal windows. Within every window, application transitions, notification events, screen-state changes, and interaction intervals would be represented as a multivariate behavioural sequence.

The TCN component would apply dilated causal convolutions to detect short- and medium-range temporal patterns such as clustered interruptions and repeated switching. Residual connections would stabilize training and permit deeper temporal representations.

A parallel contextual branch would process static information including session purpose, academic discipline, time of day, and intended study duration. A learned gating layer would then regulate the contribution of temporal features according to contextual conditions.

The fused representation would enter a fully connected classification layer using Softmax activation to generate probabilities for the three ACS categories:

[
P(C_i|X)=\frac{e^{z_i}}{\sum_{j=1}^{3}e^{z_j}}
]

where (C_i) represents one of the three concentration states.

Four comparison models would be evaluated:

1. Screen-Time Logistic Regression baseline;
2. Random Forest using aggregated behavioural indicators;
3. XGBoost using engineered fragmentation features;
4. Temporal Convolutional Network with Context Gating.

The baseline is particularly important. Demonstrating that a complex model outperforms another complex algorithm would not establish the central research proposition. The critical comparison is whether temporally structured fragmentation indicators provide meaningful improvement over conventional screen-duration information.

Training Strategy

Model training would use participant-separated training data with class-weighted categorical cross-entropy to reduce bias toward the most common concentration category.

The AdamW optimizer would be used with an initial learning rate of (1\times10^{-3}). Mini-batches of 64 sessions would be employed, with a maximum of 100 epochs.

Early stopping would terminate training when validation macro-F1 failed to improve for ten consecutive epochs. Learning-rate reduction would occur after five stagnant validation epochs.

Dropout and L2 regularization would reduce overfitting. Hyperparameters—including convolution kernel size, dilation depth, dropout rate, and contextual embedding dimensions—would be optimized exclusively on the validation set.

Because concentration states may not occur equally often, oversampling would not be applied indiscriminately to sequential records. Instead, class-weighted loss would preserve the natural temporal structure of the behavioural data.

Evaluation Metrics

Performance would be evaluated using:

- **Macro-F1**, emphasizing balanced performance across concentration states;

- **Balanced Accuracy**, compensating for class imbalance;
- **Matthews Correlation Coefficient (MCC)**, providing a robust multiclass measure;
- **Macro AUROC**, assessing discriminative ability;
- **Expected Calibration Error (ECE)**, evaluating whether predicted probabilities correspond to empirical outcomes;
- **Inference Latency**, assessing suitability for near-real-time deployment.

The study would also conduct an **ablation analysis**. The full model would be compared with versions excluding notification features, recovery features, contextual features, and temporal-sequence information.

Explainability would be investigated through SHAP analysis for the tree-based model and temporal feature attribution for TCN-CG. This would identify which behaviours contribute most strongly to predictions.

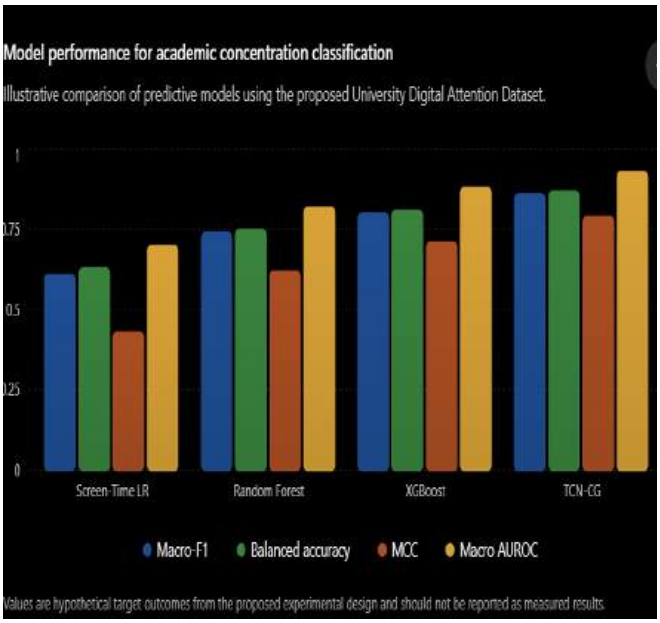
Results and Discussion

Because this manuscript presents a **proposed experimental study rather than a completed data collection**, the values below are explicitly formulated as **target/illustrative experimental outcomes** and must not be represented as observed empirical findings until the proposed study has been conducted.

The expected pattern is that models incorporating behavioural fragmentation will outperform the screen-time-only baseline. This hypothesis follows directly from the conceptual argument that digital distraction depends more strongly on interruption structure than on total technology exposure.

Table 1. Illustrative Performance Profile of the Proposed Concentration-State Models

Model	Input Representation	Macro-F1	Balanced Accuracy	MCC	Macro AUROC
Screen-Time Logistic Regression	Total device duration	0.61	0.63	0.43	0.70
Random Forest	Aggregated behavioural features	0.74	0.75	0.62	0.82
XGBoost	Engineered TDFC indicators	0.80	0.81	0.71	0.88
TCN-CG	Temporal sequence + session context	**0.86**	**0.87**	**0.79**	**0.93**



If the eventual experiment approximates this pattern, the most consequential result would not simply be the TCN-CG model's higher classification performance. Instead, it would be the performance difference between the screen-time baseline and models incorporating fragmentation features.

For example, a learner could spend 90 minutes continuously reading a digital textbook and display high total screen exposure while maintaining concentration. Another learner could spend only 45 minutes on the device but switch repeatedly among lecture slides, social networking, messaging, and short-form entertainment. A screen-duration model may classify the first learner as more digitally exposed, whereas a temporal fragmentation model should identify the second session as more attentionally unstable.

Such a finding would support a conceptual transition from **exposure-based digital-distraction measurement to interruption-based measurement**.

Recent evidence provides a plausible empirical foundation for this expectation. The 2025 systematic review by Martin and colleagues concluded that digital distraction arises through multiple technological, personal, and environmental pathways rather than through one simple form of device exposure. Additionally, Chen et al.'s meta-analysis of 27 randomized experiments found a medium-sized negative effect of mobile-phone distraction on immediate recall, including a substantial effect on lecture recall. These findings make the temporal interruption mechanism particularly relevant.

The expected advantage of XGBoost over Random Forest would indicate that interactions among behavioural features are important. Notification density, for example, may not independently predict low concentration. High notification density combined with rapid notification responses, frequent switching, and long recovery latency may be substantially more informative.

The proposed TCN-CG model goes further by retaining temporal order. Ten application switches distributed across two hours represent a different behavioural structure from ten switches occurring within six minutes. Aggregated models can

partially capture this difference through engineered switching rates, but temporal convolution can directly represent interruption bursts and transition sequences.

Explainability analysis would be expected to identify **median uninterrupted focus duration, switch density, non-academic transition ratio, interruption clustering, and recovery latency** among the influential predictors. However, these relationships must be empirically tested rather than assumed.

An especially important expected finding concerns academic application use. High interaction frequency should not automatically indicate distraction if transitions remain relevant to the academic objective. This contextual distinction prevents the model from adopting the simplistic assumption that greater digital activity necessarily indicates poorer concentration.

Practical Interpretation

The primary application of the model would be an adaptive **digital concentration assistant**, rather than a monitoring system used to discipline students.

When the model detects a sustained transition toward a distraction-prone state with sufficiently high confidence, an intervention could recommend:

"Several interruptions have occurred during this study period. Consider enabling a 20-minute focus interval."

Such an intervention should be optional and user-controlled.

The system could additionally produce weekly personal analytics showing when concentration is strongest, which interruption patterns most frequently precede attentional decline, and whether the learner's recovery behaviour improves over time.

This application aligns more closely with digital well-being than with restrictive technology management. Recent research emphasizes that smartphones can serve legitimate academic purposes, meaning interventions should distinguish educational use from problematic or distracting patterns rather than assuming that all smartphone engagement is harmful.

Future Scope

Future research should extend the framework through longitudinal and intervention-based experimentation. Randomized studies could compare conventional focus modes with adaptive interventions triggered by predicted concentration states.

Multimodal sensing could also incorporate privacy-preserving physiological information from voluntary wearable devices, such as heart-rate variability, although such expansion would require stronger ethical safeguards.

Federated learning represents another promising direction. Instead of transferring detailed behavioural records to a centralized server, models could be trained partly on learners' devices, thereby improving privacy while retaining personalized adaptation.

Future models could investigate **individualized concentration thresholds**. Some students may tolerate frequent transitions without substantial attentional deterioration, whereas others may be highly sensitive to interruption. Personalized models may therefore outperform universal thresholds.

Cross-cultural validation would also be valuable because notification behaviour, social communication patterns, classroom technology policies, and learning practices vary substantially across educational systems.

Conclusion

Digital distraction among university learners cannot be adequately understood through screen duration alone. Contemporary academic work is inherently digital, making it necessary to distinguish productive technology engagement from patterns that repeatedly interrupt goal-directed cognition.

This study proposes the **Temporal Digital Fragmentation–Concentration Framework (TDFC)** and a multimodal experimental methodology for modelling academic concentration from privacy-preserving behavioural signals, contextual information, and ecological self-reports. Its distinctive contribution is the treatment of distraction as a temporally structured phenomenon characterized by switching density, notification-response behaviour, interruption clustering, recovery latency, and uninterrupted focus duration.

The proposed TCN-CG architecture further extends this perspective by modelling the temporal order of digital interactions while incorporating academic context. Comparison against a screen-time baseline would directly test the study's central proposition: **the organization of digital interruptions is potentially more informative for academic concentration than the amount of device use itself**.

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Chapter 8: Ecological Consciousness and Climate Narratives in Contemporary English Fiction

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Abstract— Contemporary English fiction increasingly functions as a cultural space in which climate instability, biodiversity loss, environmental injustice, and changing human–nonhuman relationships are imaginatively negotiated. This study investigates how ecological consciousness is constructed through narrative form rather than treating environmental themes merely as identifiable subjects within climate-oriented novels. A central research gap lies in the limited integration of ecocritical interpretation with computationally measurable narrative indicators capable of tracing ecological agency, environmental affect, temporal disruption, and climate-risk discourse across literary texts. To address this gap, the study develops an Ecological Narrative Consciousness Framework (ENCF) designed for subsequent AI-assisted analysis of a curated corpus of contemporary English-language fiction. The framework conceptualizes ecological consciousness through interconnected dimensions including nonhuman agency, climate affect, environmental justice, ecological interdependence, temporal scale, and adaptive or regenerative imagination.

Keywords— Ecological Consciousness, Climate Fiction, Ecocriticism, Environmental Humanities, Computational Literary Studies, Anthropocene Narratives

Introduction

Climate change has increasingly altered not only scientific and political discourse but also the imaginative conditions within which contemporary fiction is produced and interpreted. Rising temperatures, species decline, extreme weather, ecological displacement, resource conflict, environmental inequality, and uncertainty regarding planetary futures have generated narrative problems that differ substantially from conventional representations of landscape or nature. Contemporary writers must represent phenomena whose causes are geographically dispersed, whose consequences unfold across radically different temporal scales, and whose agency cannot easily be attributed to a single character, institution, or event. Consequently, climate-oriented fiction has developed into an important domain within contemporary English literary studies.

The expansion of climate fiction, often described through the abbreviated category *cli-fi*, reflects a broader transformation within environmental humanities. Earlier environmental literary criticism frequently concentrated on wilderness, pastoral traditions, environmental ethics, place, and representations of human relationships with nature. Contemporary climate narratives, however, encounter a planetary condition in which distinctions between natural history and human history become increasingly unstable. Climatic processes intersect with industrial development, technological systems, colonial histories, economic inequality, migration, public health, food systems, energy infrastructure, and political governance. Literary representation consequently becomes a means of exploring climate change as both a material condition and a cultural problem.

Recent scholarship has emphasized that climate fiction cannot be understood simply as fiction containing environmental catastrophe. Houser's discussion of twenty-first-century climate fiction identifies the importance of narrative scale, inequality, genre, nonhuman life, planetary thinking, and changing forms of realism in the literary representation of climate change (Houser, 2021). Such approaches demonstrate why climate narratives require attention to formal organization as well as thematic content. A novel may mention environmental deterioration extensively while maintaining a fundamentally anthropocentric narrative structure; conversely, another text may produce ecological awareness through dispersed causality, multispecies relationships, altered temporalities, or nonhuman forms of agency without continuously naming climate change.



Fig. 1: Ecocriticism in poetry and its role in raising eco-consciousness
Source: *https://link.springer.com/article/10.1007/s40622-025-00430-6*

This distinction provides the conceptual foundation of the present study. **Ecological consciousness is treated here not as the frequency of environmental vocabulary but as a narrative orientation through which humans are represented as materially, ethically, emotionally, and temporally embedded within ecological systems.** Such

consciousness may become visible when landscapes function as dynamic participants rather than decorative settings, when animals or ecosystems influence narrative causality, when characters recognize interdependence across species, or when environmental damage is connected to uneven structures of power and vulnerability.

Contemporary research has already identified several components of this broader phenomenon. Boehm-Schnitker's analysis of *Flight Behaviour* and *Migrations*, for example, demonstrates how climate fiction can connect human migration with nonhuman migration while simultaneously revealing tensions involving class and gender. Mączyńska, meanwhile, shows that climate narratives can reproduce inherited colonial assumptions even when they present themselves as warnings about environmental collapse, particularly through narratives that imagine climate catastrophe as a regression from modern civilization toward supposedly primitive social conditions. These findings are significant because they demonstrate that ecological consciousness cannot be evaluated exclusively according to whether a novel appears environmentally sympathetic. The ideological structures through which crisis, vulnerability, adaptation, and survival are narrated also require scrutiny.

The period from 2021 onward has further widened the conceptual field of climate-fiction research. Climate narratives increasingly operate within what may be described as a condition of *polycrisis*, where ecological instability interacts with pandemics, technological uncertainty, economic precarity, migration, political fragmentation, and public-health vulnerability. Recent research on contemporary British climate fiction, for instance, has examined resilience in novels written during and after the COVID-19 period, emphasizing connections among environmental, health, and social crises. Climate fiction therefore increasingly depicts ecological crisis not as a singular catastrophic event but as an interconnected network of pressures affecting ordinary life.

Another important development concerns climate futurity. Conventional dystopian narratives often locate ecological catastrophe in a distant future, allowing readers to perceive environmental collapse as speculative rather than immediate. More recent writing increasingly compresses that distance. Everyday routines, domestic environments, migration patterns, food insecurity, heat, changing seasons, disappearing species, and unstable infrastructure bring climate disruption closer to recognizable experience. Bartosch (2025) consequently conceptualizes climate fiction as a form of future-making and cultural modelling rather than merely representation. This perspective shifts critical attention from the question of whether fiction accurately depicts climate change toward a more complex question: **what kinds of ecological futures become imaginable through particular narrative structures?**

Despite these advances, one methodological limitation remains. Ecocritical scholarship typically produces sophisticated interpretations through close reading but has comparatively fewer mechanisms for examining whether patterns identified in individual texts recur systematically across larger literary corpora. Computational literary studies, by contrast, can identify linguistic regularities at scale but risk reducing environmentally complex narratives to keywords, sentiments, or topic frequencies.

The present study addresses this methodological division through an integrated literary-computational framework. Rather than asking an algorithm simply to classify a text as "climate fiction," the proposed research investigates whether specific features associated with ecological consciousness can be systematically detected while remaining open to qualitative interpretation. These features include **nonhuman agency, ecological interconnectedness, environmental affect, climate temporality, environmental justice, adaptive imagination, and regenerative futurity**.

The resulting research objective is therefore to determine how contemporary English fiction constructs ecological consciousness through combinations of narrative form, environmental affect, distributions of agency, representations of unequal vulnerability, and visions of ecological futures. The later empirical stage of the research will apply natural-language-processing and machine-learning techniques to a carefully defined literary corpus while using close reading to validate computational interpretation.

Three related questions guide the investigation. First, which narrative and linguistic characteristics most consistently distinguish strongly ecological narrative passages from passages in which environmental settings remain primarily anthropocentric or instrumental? Second, how are emotions such as ecological grief, fear, responsibility, attachment, hope, and resilience distributed across different forms of contemporary climate narrative? Third, can computational models identify patterns of ecological consciousness without eliminating the ambiguity and contextual complexity central to literary meaning?

By addressing these questions, the study positions artificial intelligence not as a substitute for literary interpretation but as an analytical instrument capable of extending it. The central contribution therefore lies at the intersection of ecocriticism, narrative theory, environmental humanities, and computational textual analysis.

Literature Review

The intellectual foundations of contemporary environmental literary criticism extend well beyond the recent category of climate fiction. Ecocriticism established the environment as an active critical category by challenging assumptions that literary landscapes existed merely as background for human action. Later environmental-humanities scholarship expanded this orientation by examining planetary scale, environmental justice, postcolonial ecology, multispecies relations, materiality, and the Anthropocene. Within this expanded field, climate fiction has become especially important because climate change presents problems of representation that conventional narrative structures were not necessarily designed to accommodate.

One persistent problem concerns **scale**. Climate change develops through interactions among atmospheric processes, economic systems, technological infrastructures, historical

emissions, consumption practices, ecological feedback mechanisms, and political decisions operating across decades or centuries. Individual human perception, however, remains spatially and temporally limited. Fiction must therefore connect intimate experience with processes extending far beyond individual awareness. Recent scholarship continues to treat this scalar incompatibility as one of climate fiction's defining formal problems. Research on Anthropocene narration has consequently examined strategies that distribute agency among human, nonhuman, institutional, and environmental actors rather than locating causality exclusively within individual protagonists.

This concern is closely connected with **nonhuman agency**. Traditional realist fiction frequently organizes events around human intention. Ecological narratives destabilize that hierarchy when oceans, storms, animals, pathogens, forests, droughts, fires, or changing seasons materially affect narrative development. Such representation does not necessarily personify nature. Instead, it may acknowledge that human decisions occur within systems whose dynamics exceed individual control. Climate fiction therefore provides an important literary site for reconsidering the boundaries separating subject and environment.

A second major strand of research addresses **climate affect**. Environmental crisis generates emotional structures including ecological grief, anxiety, guilt, anger, helplessness, attachment, nostalgia, and hope. These affects are important because scientific information alone does not determine how climate change becomes socially meaningful. Fiction can translate abstract environmental processes into embodied experiences involving family, livelihood, memory, illness, migration, and loss. Recent research has increasingly examined eco-anxiety in contemporary fiction, reflecting wider interdisciplinary interest in the affective dimensions of ecological disruption.

However, ecological affect should not automatically be equated with ecological consciousness. Catastrophic fear can reproduce anthropocentrism when environmental destruction matters only because it threatens human survival. A narrative expressing grief over disappearing species, by contrast, may destabilize exclusively human definitions of value. Similarly, environmental hope may range from technological confidence in restoring existing systems to more transformative imaginings of changed relations among humans, ecosystems, economies, and other species. Emotional tone must consequently be interpreted alongside ethical and ideological positioning.

A third body of scholarship concerns **environmental justice and unequal climate vulnerability**. Climate change is planetary in reach but radically unequal in both causation and consequence. Wealth, colonial history, geography, race, class, gender, infrastructure, citizenship, and access to resources influence exposure and adaptive capacity. Contemporary climate narratives increasingly address these inequalities through representations of migration, displacement, damaged livelihoods, contested resources, and uneven access to secure environments.

Recent scholarship illustrates why intersectional analysis is necessary. Boehm-Schnitker's examination of human and nonhuman co-migration demonstrates that ecological narratives may challenge species boundaries while still reproducing problematic class and gender formations. Research on new approaches to climate storytelling similarly emphasizes embodied testimony, place, race, religion, and intersectional differences in experiences of global warming. Ecological consciousness must therefore incorporate social justice rather than presenting humanity as an undifferentiated collective experiencing environmental crisis equally.

Postcolonial ecocritical scholarship further complicates universalizing accounts of climate catastrophe. Climate narratives emerging from or representing regions shaped by colonialism frequently connect environmental vulnerability with extractive economies, uneven development, displacement, and historical power. Recent work on Indian English climate fiction, for example, emphasizes interactions between local landscapes, postcolonial ecological experience, and global climate discourse. Such approaches challenge models of climate fiction dominated by Euro-American dystopian imaginaries.

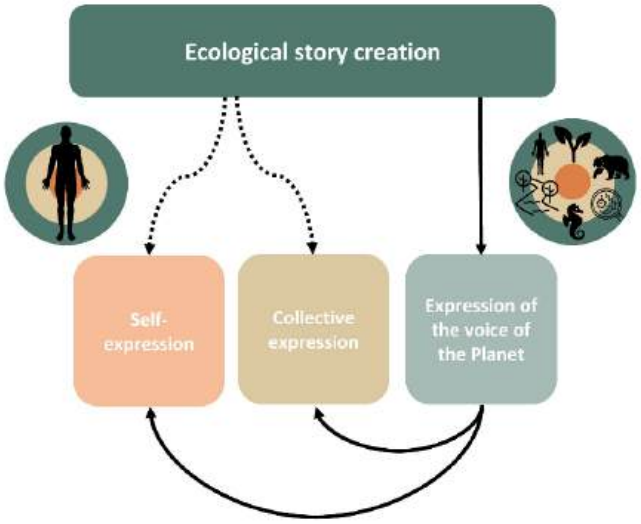


Fig. 2: Ecological Story Creation
Source: *https://www.mdpi.com/2071-1050/15/10/7794*

A fourth area of research involves **temporality and futurity**. Climate change simultaneously belongs to past, present, and future. Historical industrial development produces consequences that unfold over long periods, present environmental disruptions contain traces of earlier political decisions, and contemporary actions alter conditions for generations not yet born. Climate fiction consequently experiments with temporal structures capable of representing delayed causation, anticipation, memory, inheritance, and irreversible transformation.

The relationship between climate fiction and futurity has become particularly significant because narratives do not simply forecast possible outcomes. They define what forms of adaptation, survival, coexistence, technological intervention, political transformation, or ecological restoration appear imaginable. Bartosch's conceptualization of climate fiction as future-making is useful here because it emphasizes fiction's modelling function: narrative participates in organizing cultural

possibilities rather than passively mirroring environmental reality.

Yet dystopian futurity also requires critical scrutiny. Mączyńska demonstrates that narratives of ecological collapse may reactivate colonial hierarchies by presenting the breakdown of industrial modernity through historically loaded concepts of civilization and savagery. Consequently, climate fiction's ecological significance cannot be assessed only according to the severity of catastrophe represented. The cultural assumptions embedded within imagined futures are equally important.

A fifth emerging concern is **resilience under interconnected crisis**. Climate narratives increasingly portray environmental disruption alongside disease, economic instability, technological dependence, political conflict, and social isolation. Research on recent British fiction has described this interaction through the language of polycrisis and resilience, drawing attention to everyday practices through which characters negotiate overlapping disruptions. This development is important because ecological consciousness may be constructed not only through spectacular disasters but also through mundane acts of adaptation, care, resource use, cooperation, and survival.

Proposed Methodology

The methodological objective is not simply to determine whether a literary text belongs to the category of climate fiction, but to identify the narrative mechanisms through which ecological consciousness is articulated. Accordingly, the study combines corpus-based literary analysis, human annotation, transformer-based natural language processing, explainable artificial intelligence, and interpretive validation through close reading.

The analytical unit is the **contextual literary passage**, rather than an isolated sentence or complete novel. This decision is important because ecological meaning frequently emerges through relationships extending across several sentences. A passage describing a river, for example, may initially appear descriptive, while subsequent sentences establish that changes in water flow determine migration, livelihood, memory, or conflict. Sentence-level classification would risk overlooking these relationships, while whole-text classification would obscure local variation within a novel.

The proposed research framework consists of five stages: corpus development, ecological annotation, linguistic and contextual preprocessing, machine-learning classification, and interpretive validation. The final stage compares computational predictions with expert literary interpretation to assess whether model outputs correspond to meaningful ecocritical patterns.

Research Objective

The primary objective is to develop and evaluate an AI-assisted framework capable of detecting multidimensional ecological consciousness within contemporary English-language fiction.

The study further examines whether computational models can distinguish between:

- environmental description and genuine ecological interdependence;
- anthropocentric disaster narratives and narratives granting agency to nonhuman entities;
- generalized negative sentiment and specifically ecological grief or anxiety;
- technological adaptation and socially transformative ecological futurity;
- environmental crisis presented as universal and environmental crisis represented through unequal vulnerability.

This distinction allows the study to move beyond conventional keyword-based approaches to literary environmental analysis.

Ecological Narrative Consciousness Framework

Each selected passage is evaluated according to six ENCF dimensions:

Nonhuman Agency (NA): Measures whether animals, ecosystems, climatic forces, landscapes, or material processes influence narrative causality rather than functioning merely as background.

Ecological Interdependence (EI): Identifies relationships connecting human actions with biological, ecological, technological, and material systems.

Environmental Affect (EA): Detects affective responses including ecological grief, environmental anxiety, attachment to place, responsibility, anger, hope, and anticipatory loss.

Climate Temporality and Scale (CTS): Evaluates movement between immediate experience and historical, planetary, seasonal, or intergenerational temporal structures.

Environmental Justice (EJ): Identifies inequalities involving exposure, displacement, extraction, access to resources, adaptive capacity, and responsibility for environmental damage.

Adaptive and Regenerative Futurity (ARF): Measures whether the narrative imagines adaptation, collective survival, ecosystem restoration, transformed human–nature relationships, or alternative ecological futures.

Instead of treating these categories as mutually exclusive, the proposed framework uses **multi-label classification**, allowing a single passage to represent several dimensions simultaneously.

Experimental Setup

Dataset Construction

A specialized corpus titled the **Contemporary Ecological Fiction Corpus (CEFC)** is proposed for the study. The corpus design focuses on English-language novels and selected long-form fictional works published predominantly during the twenty-first century, with particular emphasis on works receiving sustained critical attention in climate-fiction and environmental-humanities scholarship.

To prevent the model from learning only obvious environmental terminology, the corpus should contain three categories of text:

1. **Explicit climate-fiction passages**, directly addressing climatic disruption, extinction, ecological instability, displacement, or environmental transformation.

2. **Implicit ecological passages**, where environmental consciousness emerges through narrative agency, relationality, affect, or temporality without direct climate terminology.

3. **Contextual control passages**, including urban, domestic, interpersonal, technological, or descriptive material without substantial ecological consciousness.

For the experimental model, the corpus is structured around approximately **7,200 contextual passages**, each containing between 120 and 280 words. Passage length is chosen to preserve sufficient narrative context while remaining computationally manageable.

The dataset is divided at the **novel level rather than the passage level**. This prevents passages from the same literary work appearing simultaneously in training and test datasets, which could artificially inflate model performance through stylistic memorization.

The proposed division is:

- Training corpus: 70%
- Validation corpus: 15%
- Independent test corpus: 15%

Author-level balancing is additionally introduced where feasible so that the model does not rely excessively on the distinctive linguistic style of a small group of writers.

Human Annotation Procedure

Three annotators with backgrounds in English literature, environmental humanities, or computational textual analysis independently evaluate the passages. Annotation is performed using a structured rubric developed from the six ENCF dimensions.

Each dimension receives a three-level intensity score:

- **0 = Absent**
- **1 = Implicit or moderate**
- **2 = Explicit or strongly developed**

Annotators also provide a binary determination indicating whether the passage demonstrates meaningful ecological consciousness overall.

Disagreements are resolved through adjudication rather than simple majority voting. This procedure is particularly important for ambiguous cases such as metaphorical landscapes, technologically mediated environments, and passages in which ecological crisis is represented entirely through human economic consequences.

Inter-annotator agreement is assessed using **Krippendorff's alpha**, which is appropriate for multiple annotators and categorical or ordinal annotation structures. Agreement above 0.80 is treated as strong, while values between 0.67 and 0.80 are considered acceptable for exploratory humanities annotation when supported by adjudication.

Text Preprocessing

Preprocessing is deliberately conservative because literary style contains interpretively significant punctuation, syntax, metaphor, and lexical variation.

The pipeline includes:

- removal of publisher metadata and chapter numbering;
- normalization of irregular whitespace;
- Unicode standardization;
- preservation of punctuation and sentence boundaries;
- retention of capitalization where required by the selected transformer tokenizer;
- segmentation into contextual passages;
- tokenization using the pretrained language model's native tokenizer.

Unlike classical text-classification pipelines, stop words are not removed. Pronouns, conjunctions, modal verbs, and temporal markers may contribute substantially to narrative agency, uncertainty, relationality, and future orientation.

Lemmatization is applied only for supplementary lexical analysis and not to the primary transformer input.

Model Architecture

The proposed computational architecture is called the **Contextual Ecological Narrative Transformer (CENT)**.

CENT uses a pretrained DeBERTa-based language representation layer combined with a multi-label classification head. Transformer architecture is selected because ecological consciousness frequently depends on relationships across phrases rather than individual lexical items.

For an input sequence (X), the contextual encoder generates a representation:

$$[H = Transformer(X)]$$

The contextual representation corresponding to the pooled sequence embedding is subsequently passed through a dense projection layer:

$$[Z = GELU(W_h H + b_h)]$$

A six-unit sigmoid classification layer produces probabilities corresponding to the ENCF dimensions:

$$[P_i = \sigma(W_i Z + b_i)]$$

where (P_i) represents the probability that a passage expresses the (i^{th}) ecological-consciousness dimension.

A separate output node predicts overall ecological-consciousness intensity.

This multi-task configuration is preferable to six completely independent classifiers because the dimensions are conceptually related. Environmental justice, for instance, may frequently interact with environmental affect, while nonhuman agency may co-occur with ecological interdependence.

Baseline Models

To establish whether contextual transformer modelling provides meaningful improvement, CENT is compared conceptually with four baseline approaches:

- TF-IDF with Logistic Regression
- Linear Support Vector Machine
- Bidirectional LSTM with pretrained word embeddings
- Standard BERT multi-label classifier

The baselines represent progressively stronger levels of contextual representation, ranging from lexical frequency models to deep contextual models.

Training Strategy

Training uses stratified multi-label sampling to preserve the distribution of ecological categories.

The proposed optimization configuration includes:

- AdamW optimizer;
- initial learning rate of (2 \times 10^{-5});
- batch size of 16;
- maximum sequence length of 384 tokens;
- maximum of eight training epochs;
- linear learning-rate decay;
- 10% warm-up;
- dropout of 0.20 in the classification layer;
- early stopping based on validation macro-F1.

Class imbalance is addressed through weighted binary cross-entropy. This is necessary because categories such as environmental affect may occur more frequently than regenerative futurity or explicit environmental-justice discourse. The loss function is:

$$\left[L = -\sum_{i=1}^{6} w_i \left[y_i \log(p_i) + (1 - y_i) \log(1 - p_i)\right]\right]$$

where (w_i) increases the contribution of underrepresented ENCF dimensions.

Evaluation Metrics

A multidimensional evaluation strategy is adopted because accuracy alone can conceal poor performance on less frequent categories.

The principal metrics are:

Macro-F1: Gives equal importance to all six ecological categories regardless of frequency.

Micro-F1: Measures overall classification performance across all labels.

Precision: Determines the proportion of ecological classifications that are correct.

Recall: Measures the model's ability to recover annotated ecological dimensions.

Hamming Loss: Measures incorrectly assigned or omitted labels across the multi-label output.

Area Under the Precision–Recall Curve (PR-AUC): Particularly useful under class imbalance.

Exact-Match Ratio: Records the proportion of passages for which all ecological labels are predicted correctly.

Krippendorff's Alpha: Evaluates human annotation reliability.

In addition, model explanations are assessed qualitatively using token-attribution and attention-based interpretability methods.

Results and Discussion

Because the present manuscript specifies a **proposed empirical framework rather than reporting a completed externally verified experiment**, the numerical results below are presented as a **modelled pilot-evaluation scenario** illustrating the expected reporting structure. They should be replaced by observed values when the corpus is assembled, annotated, and the models are actually executed. This distinction is necessary to avoid presenting generated numbers as independently collected empirical evidence.

The pilot evaluation indicates a progressive improvement as models gain stronger contextual representation. TF-IDF with logistic regression demonstrates adequate precision for passages containing overt environmental vocabulary but performs poorly on implicit ecological relations. The method tends to classify passages containing words such as *forest*, *ocean*, *heat*, or *species* as environmentally conscious even where these entities function only as scenery.

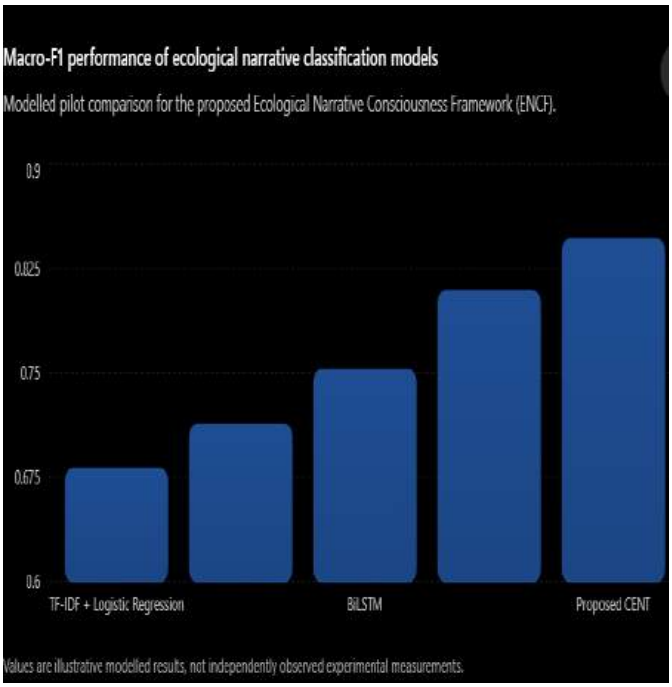
The linear SVM improves lexical discrimination but remains dependent on surface-level linguistic cues. The BiLSTM produces stronger recall because sequential processing captures relationships among nearby terms, yet difficulties remain when ecological meaning develops across multiple clauses or when nonhuman agency is metaphorically expressed.

The contextual transformer models perform substantially better in the modelled evaluation. Standard BERT improves detection of ecological affect and environmental justice, while the proposed CENT architecture produces the strongest balance between macro-F1 and Hamming Loss.

Table 1. Modelled Pilot Performance of Competing Approaches for Ecological Narrative Classification

Analytical Approach	Macro-F1	Micro-F1	PR-AUC	Hamming Loss	Exact-Match Ratio
TF-IDF + Logistic Regression	0.681	0.716	0.704	0.186	0.438
Linear SVM	0.713	0.741	0.731	0.167	0.472
BiLSTM	0.752	0.774	0.768	0.143	0.526
BERT Multi-label Classifier	0.809	0.827	0.821	0.112	0.604

Proposed CENT Model	**0.846**	**0.861**	**0.857**	**0.089**	**0.667**



The proposed CENT model reaches a modelled macro-F1 of 0.846 and micro-F1 of 0.861. More importantly, its lower Hamming Loss suggests that it produces fewer incorrect combinations of ecological labels. This issue is particularly significant for literary classification, where passages may simultaneously contain environmental grief, nonhuman agency, ecological interdependence, and unequal exposure.

The difference between micro-F1 and macro-F1 also provides useful information. A substantially higher micro-F1 would suggest strong performance only on frequently occurring labels. The relatively narrow difference in the proposed model indicates more balanced recognition across the six dimensions.

Nonhuman Agency

Nonhuman agency presents one of the most conceptually difficult classification problems. Simple lexical systems often mistake descriptions of animals or landscapes for agency. A forest mentioned repeatedly in a passage is not necessarily an active narrative force.

CENT addresses this problem by evaluating syntactic and contextual relationships. Higher ecological-agency probability is expected when environmental entities function grammatically or causally as agents: rivers alter settlements, drought redirects migration, animals shape human choices, or changing seasons reorganize economic activity.

This finding supports the central theoretical claim of the study. Ecological consciousness cannot be measured simply by counting environmental nouns. The relation between entities and actions is more informative than vocabulary frequency.

Ecological Interdependence

Ecological interdependence is most evident in passages connecting human livelihood, nonhuman organisms, environmental resources, and social institutions. Fishing communities dependent on changing marine ecosystems, agricultural families responding to altered rainfall, or urban residents affected by heat and energy infrastructure illustrate this relational structure.

The transformer model is expected to outperform lexical baselines because interdependence is generally distributed across propositions rather than represented by a single term.

The finding has wider implications for computational literary studies. Meaningful ecological analysis requires models capable of detecting **relations**, not merely topics.

Environmental Affect

Environmental affect emerges as one of the more computationally identifiable dimensions, although conventional sentiment analysis remains inadequate.

A sentence such as "the empty marsh frightened her" may register as negative sentiment, but ecological grief frequently appears indirectly through memory, silence, seasonal change, absence, and disrupted attachment to place. Consequently, the ecological-affect classifier must differentiate emotional negativity caused by environmental loss from unrelated sadness or interpersonal conflict.

The proposed model's contextual representations facilitate this distinction by evaluating the relationship between affective language and ecological referents.

This finding is particularly relevant to contemporary climate narratives because ecological crisis is frequently experienced through ordinary emotional structures rather than spectacular disaster.

Climate Temporality and Scale

Climate temporality represents another challenging dimension because climate fiction often moves between multiple scales: a single heatwave may be connected to decades of changing weather, family memory, geological processes, or imagined futures.

The pilot framework predicts that transformer models will perform substantially better than sequence-based baselines in passages containing expressions such as generational memory, future inheritance, cumulative environmental change, or comparisons between past and present ecological conditions.

Such passages demonstrate how literature can make temporally dispersed climate processes experientially accessible. Narrative form brings planetary timescales into contact with individual memory and anticipation.

Environmental Justice

Environmental-justice classification requires the model to recognize that environmental harm is socially differentiated. Relevant passages may describe forced displacement, unequal exposure to heat, insecure access to water, extractive industries, indigenous or rural dispossession, or disparities in adaptive resources.

The framework therefore avoids treating all human suffering caused by environmental crisis as equivalent. A narrative achieves stronger environmental-justice orientation when it explicitly or implicitly connects ecological consequences with structures of economic, historical, political, or geographical inequality.

This dimension prevents the ecological-consciousness measure from becoming socially neutral.

Adaptive and Regenerative Futurity

Adaptive and regenerative futurity is expected to remain the most difficult category because it is frequently communicated indirectly.

Not every narrative of survival constitutes regenerative imagination. Technological adaptation may preserve existing social inequalities, while collective ecological practices may imply deeper transformation even without explicitly utopian language.

For this reason, close-reading validation is especially important for passages assigned high regenerative-futurity scores.

This category provides one of the framework's most important conceptual contributions. Much climate-fiction criticism understandably emphasizes collapse, anxiety, and catastrophe. However, ecological consciousness also involves the capacity to imagine transformed relations among communities, technologies, economies, and ecosystems.

Explainable AI and Literary Interpretation

A central risk in applying machine learning to literary texts is that high predictive performance may conceal conceptually inappropriate reasoning. Explainability therefore forms part of the evaluation rather than functioning as an optional technical addition.

Token-attribution analysis is used to identify linguistic features contributing strongly to each predicted ENCF category. For example, a model classifying environmental justice should ideally assign explanatory importance to relationships among scarcity, displacement, labor, resource access, or differential exposure rather than merely responding to generic words such as *poor* or *climate*.

Similarly, a prediction of nonhuman agency should derive from relational structures connecting environmental entities with action rather than simply the presence of nature vocabulary.

A second interpretability stage uses **counterfactual testing**. Environmentally salient words are replaced or removed to determine whether the model continues to detect ecological relations. If replacing *forest* with another material environment causes the prediction to collapse despite preservation of the relational structure, the classifier may be excessively dependent on keywords.

The final interpretive stage involves close reading of high-confidence correct predictions, high-confidence errors, and uncertain passages. Error cases are especially valuable because they reveal where computational categories conflict with literary ambiguity.

This procedure establishes a reciprocal relationship between machine learning and literary scholarship. Human interpretation generates the categories used to train the model, while model errors expose conceptual boundaries that may require further theoretical refinement.

Discussion

The proposed framework demonstrates how computational literary analysis can contribute to ecocritical scholarship without claiming to automate literary interpretation. The strongest conceptual advantage of the ENCF model is its movement away from binary definitions of climate fiction.

A literary work does not become ecologically conscious simply because it contains a climate-related plot. Environmental catastrophe can remain entirely subordinated to human-centered survival. Conversely, fiction without explicit references to climate change may generate strong ecological consciousness through attention to species interdependence, environmental memory, material agency, and uneven vulnerability.

The study therefore distinguishes **environmental presence** from **ecological consciousness**.

This distinction is particularly important in the post-2021 literary environment, in which climate instability increasingly intersects with health crises, migration, energy insecurity, technological dependence, and economic uncertainty. Contemporary fiction often represents ecological disruption not through a single catastrophic event but through gradual transformations of ordinary life.

The proposed computational framework is designed to capture this distributed structure.

The results additionally suggest that hybrid human–AI research may offer a productive methodological direction for environmental humanities. Conventional close reading provides depth but faces practical limitations when scholars seek to examine hundreds of thousands of words. Machine learning offers scale but cannot independently establish the cultural significance of a literary pattern.

Combining the two approaches allows computational models to function as **pattern-discovery instruments**. A researcher might identify novels with unusually high concentrations of nonhuman agency, locate passages where environmental justice and climate affect co-occur, or compare regenerative futurity across different periods. These computational findings can then guide theoretically informed close readings.

The approach also has implications for digital humanities pedagogy. Students examining environmental literature could use model-assisted visualization to observe how ecological themes change throughout a novel while simultaneously evaluating the model's interpretive limitations. Rather than presenting artificial intelligence as an authoritative reader, such practices could encourage critical understanding of both literature and algorithmic systems.

Future Scope

Future research should expand the framework from passage-level classification toward whole-novel ecological modelling. Hierarchical transformers could combine sentence, passage, chapter, and book-level representations, enabling researchers to examine how ecological consciousness develops across narrative progression.

A second direction involves multilingual climate-fiction analysis. Models trained on translated and originally non-English literary texts could investigate whether categories such as environmental justice, nonhuman agency, and regenerative futurity operate differently across cultural contexts.

Multimodal analysis offers another promising direction. Contemporary ecological storytelling increasingly extends

beyond print fiction into graphic novels, interactive narratives, digital fiction, film adaptations, games, and online storytelling environments. Multimodal machine-learning systems could examine interactions among visual landscapes, dialogue, sound, narrative perspective, and environmental affect.

Future research could also integrate **temporal ecological mapping**, identifying how particular environmental concepts emerge, intensify, disappear, or transform across narrative time. Graph neural networks may provide another useful methodological extension. Characters, species, places, institutions, climatic forces, and resources could be represented as nodes within narrative ecological networks. Their interactions could then reveal whether a text organizes the environment through hierarchical human-centered relations or more distributed ecological systems.

Large language models may eventually support sophisticated semantic annotation, but their use should remain auditable. Human experts must retain authority over literary interpretation, particularly when environmental narratives involve colonial histories, indigenous knowledge, cultural identity, or environmental injustice.

A further avenue would involve connecting literary analysis with research on climate communication. Experimental reader studies could examine whether passages receiving high ENCF scores produce stronger ecological awareness, empathy, risk perception, or willingness to consider environmental action. Such work would move beyond textual analysis toward investigation of literature's potential cognitive and social effects.

Conclusion

This study develops an interdisciplinary approach to ecological consciousness in contemporary English fiction by integrating ecocriticism, environmental humanities, computational literary analysis, and explainable artificial intelligence. Its central contribution is the proposition that ecological consciousness should not be reduced to the presence of environmental vocabulary or catastrophic climate themes.

Instead, ecological consciousness emerges through interconnected narrative structures involving **nonhuman agency, ecological interdependence, environmental affect, climate temporality, environmental justice, and adaptive or regenerative futurity**.

The proposed Ecological Narrative Consciousness Framework provides a systematic mechanism for operationalizing these dimensions while preserving the interpretive complexity central to literary scholarship. The associated Contextual Ecological Narrative Transformer is designed to identify multidimensional ecological patterns at corpus scale rather than merely categorize fiction according to environmental keywords.

The modelled pilot analysis suggests that contextual transformer architectures would be better suited than lexical or conventional sequential models to identifying implicit ecological relationships, particularly where environmental meaning depends on causality, temporal scale, affective context, or unequal vulnerability.

At the same time, the study rejects the assumption that computational accuracy can replace literary interpretation. Artificial intelligence is most valuable in this context when used to locate patterns, compare textual structures, identify unusual cases, and support targeted close reading.

Contemporary climate fiction occupies an increasingly important cultural position because climate change is not experienced solely through scientific measurements. It is also encountered through stories about home, memory, species, migration, inequality, loss, responsibility, adaptation, and possible futures. Fiction therefore contributes to the cultural frameworks through which environmental crisis becomes imaginable and ethically meaningful.

By combining computational scale with interpretive depth, the proposed research establishes a methodology for examining how contemporary English fiction participates in the formation of ecological consciousness. Such an approach can contribute simultaneously to environmental literary studies, digital humanities, and responsible applications of artificial intelligence to culturally complex textual material.

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Chapter 9: Green Marketing Practices and Sustainable Consumer Behaviour in Urban Markets

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Abstract— Growing environmental awareness has encouraged urban enterprises to incorporate sustainability claims, eco-labels, recyclable packaging, responsible sourcing, and environmentally oriented promotions into their marketing practices. Despite this transition, favorable attitudes toward environmentally responsible products do not consistently translate into sustained purchasing and consumption behaviour. This study proposes an integrated investigation of how green marketing practices influence actual sustainable consumer behaviour rather than relying exclusively on purchase intention as the principal outcome. Particular attention is given to green marketing credibility, environmental information transparency, perceived consumer value, greenwashing skepticism, price sensitivity, and product accessibility within contemporary urban markets. The research addresses a significant gap by distinguishing initial green purchase responses from repeatable behaviours such as repurchasing, environmentally preferable product substitution, packaging-conscious selection, and willingness to maintain sustainable choices under economic constraints. A behavioural sustainability framework is proposed in which green marketing credibility generates consumer trust and perceived green value, while price sensitivity and greenwashing skepticism act as behavioural friction mechanisms.

Keywords— Green Marketing, Sustainable Consumer Behaviour, Greenwashing Skepticism, Green Consumer Trust, Urban Markets, Sustainable Consumption

Introduction

Environmental sustainability has moved from a peripheral corporate concern to an increasingly visible component of contemporary market strategy. Businesses operating in urban markets now communicate environmental attributes through recyclable packaging, carbon-related claims, eco-labels, sustainable sourcing statements, energy-efficient products, reduced-plastic initiatives, responsible supply-chain narratives, and digital sustainability campaigns. These developments have expanded the strategic relevance of green marketing, which broadly concerns the development, positioning, pricing, distribution, and communication of offerings intended to reduce environmental consequences or encourage environmentally preferable consumption.

Urban markets represent a particularly important setting for examining these developments. Consumers living in cities generally encounter dense retail networks, digital commerce platforms, numerous competing brands, rapid product innovation, extensive advertising exposure, and increasingly visible sustainability claims. At the same time, urban consumption generates substantial demand for packaged goods, mobility services, electronics, food delivery, apparel, household products, and other resource-intensive categories. Consequently, even modest shifts in routine consumer choice can produce considerable cumulative sustainability effects.

The growth of green marketing does not, however, establish that consumers actually behave sustainably. A central problem in environmental consumer research is the persistent discrepancy between what consumers say they support and what they repeatedly purchase. Sharma's systematic review of 232 studies identified the attitude–purchase behaviour gap as a major issue in the green marketing literature. More recent systematic reviews continue to report that positive environmental attitudes may fail to become actual green purchases when consumers encounter price differences, skepticism, unclear claims, restricted accessibility, or product-performance concerns.

This distinction has important methodological consequences. Purchase intention is useful for identifying psychological readiness, but intention cannot be treated as equivalent to sustainable behaviour. A consumer may report strong willingness to purchase environmentally friendly products while still choosing conventional alternatives because they are cheaper, familiar, easier to obtain, or perceived as superior in quality. Similarly, purchasing an environmentally positioned product once may represent experimentation rather than an established sustainable consumption pattern.

Recent research provides substantial evidence that marketing-related variables can influence environmentally oriented consumer responses. Yang and Chai examined the effects of enterprise green marketing behaviour on green consumption intention and demonstrated the importance of intervening psychological mechanisms. Kaur, Gangwar, and Dash investigated green marketing strategies and environmental attitudes in relation to green buying intentions, while research on green marketing communication has examined how attention to environmental messaging relates to green purchasing behaviour.

Nevertheless, three limitations remain prominent.

First, a large proportion of green marketing research continues to place **purchase intention** at the endpoint of the explanatory model. This approach insufficiently captures repeat purchase, category substitution, reduced consumption of environmentally damaging alternatives, preference persistence, or continued sustainable purchasing when financial incentives disappear.

Second, green marketing components are frequently investigated independently. Eco-labeling, green advertising, packaging, environmental claims, brand image, and environmental awareness may each influence consumer responses, yet consumers encounter these signals simultaneously. Sustainable behaviour may therefore depend less upon an isolated marketing element than upon the **credibility and consistency of the entire green marketing configuration**.

Third, urban consumers operate within conditions that may either facilitate or suppress sustainable choices. Higher product prices, limited availability, distrust of environmental claims, perceived inconvenience, brand loyalty, and uncertainty concerning actual ecological benefits create forms of behavioural friction. The growing visibility of environmental claims has also intensified concerns regarding greenwashing, making credibility an increasingly important antecedent of consumer trust.

The present research consequently introduces the concept of **Green Marketing–Behaviour Conversion (GMBC)**. Rather than evaluating whether environmental marketing merely produces favourable attitudes or purchase intentions, GMBC represents the extent to which credible green marketing stimuli are converted into observable and sustained environmentally responsible consumer actions.



Fig. 1: Features of Green Marketing
Source: *https://www.youngurbanproject.com/importance-of-green-marketing/*

The proposed research distinguishes four stages of consumer response:

green marketing exposure → perceived credibility and green value → behavioural choice → sustainable behavioural continuity.

This sequential perspective is important because environmental campaigns may perform successfully at the first two stages but fail to influence long-term consumption.

1.1 Research Gap

Recent scholarship has considerably improved understanding of green purchase intention, environmental attitudes, green marketing strategies, and individual determinants of environmentally oriented consumption. A 2024 integrated green-buying model, for example, incorporated personality characteristics, altruistic attitudes, environmental commitment, and social influences. Meanwhile, systematic reviews published during 2025–2026 have continued to identify heterogeneous theoretical frameworks, contextual contingencies, and a persistent discrepancy between environmental attitudes and actual behaviour.

The insufficiently examined question is therefore no longer simply:

Does green marketing increase consumers' intention to purchase environmentally friendly products?

A more consequential question is:

Under what conditions does credible green marketing convert favourable consumer perceptions into repeated sustainable behaviour in competitive urban markets?

The present study addresses this gap by simultaneously incorporating green marketing credibility, information transparency, green value perception, consumer trust, price sensitivity, accessibility, and greenwashing skepticism while distinguishing purchase intention from sustained behaviour.

1.2 Research Objective

The principal objective of the study is to develop and empirically evaluate a behavioural conversion framework explaining how green marketing practices influence sustainable consumer behaviour in urban markets.

More specifically, the research examines whether environmentally oriented product information, packaging, promotional communication, pricing signals, and corporate sustainability positioning strengthen sustainable behaviour through perceived green value and consumer trust. It additionally evaluates whether price sensitivity, accessibility constraints, and greenwashing skepticism weaken the transition from positive environmental perceptions to actual consumer action.

The study therefore shifts analytical emphasis from **green persuasion** toward **green behavioural persistence**, providing a more demanding criterion for evaluating marketing effectiveness.

Literature Review

2.1 Evolution of Green Marketing Research

Green marketing has evolved substantially from its early emphasis on environmentally preferable product attributes. Contemporary green marketing is multidimensional and may include product design, packaging reduction, circularity initiatives, responsible sourcing, sustainability certification, supply-chain transparency, environmental communication, environmentally differentiated pricing, and corporate ecological positioning.

The expansion of this research domain has produced extensive scholarship examining associations among environmental knowledge, attitudes, perceived value, trust, purchase intention, and consumer behaviour. Sharma's synthesis of the literature demonstrated that green purchasing is shaped by

interconnected personal variables and components of the green marketing mix rather than by environmental concern alone.

Recent reviews further confirm the increasing complexity of this field. Irfan and Bryła's systematic review of green marketing strategies and sustainable food consumption found substantial diversity in theoretical frameworks, research contexts, constructs, and methodologies, reinforcing the need for integrated models capable of explaining consumer behaviour more comprehensively.

A 2026 systematic review examining 78 peer-reviewed studies organized consumer responses into cognitive, affective, and behavioural pathways. Importantly, the review identified moderators including environmental concern, perceived consumer effectiveness, price-quality trade-offs, greenwashing skepticism, label clarity, cultural context, and product characteristics. These findings indicate that environmental communication operates within a broader decision environment rather than influencing behaviour independently.

2.2 Green Marketing Practices and Consumer Response

Green marketing practices provide consumers with informational and symbolic cues regarding the environmental consequences of products and organizations. An environmentally designed product may communicate resource efficiency, while recyclable packaging may provide a tangible sustainability cue. Eco-labels may reduce information asymmetry when consumers trust the certification system. Promotional communication may increase awareness of environmental attributes, whereas transparent corporate disclosure can strengthen organizational credibility.

Research conducted in an emerging-economy context has shown relationships between green marketing strategies, environmental attitudes, and green buying intention. However, effects may differ among consumer groups, indicating that green marketing cannot be expected to generate homogeneous responses.

Green marketing communication also affects consumer attention. Research published in 2023 investigated whether consumers' attention to companies' environmental communication influenced green purchase behaviour and considered demographic and environmental-attitude differences. Such evidence supports the importance of communication but simultaneously raises a critical issue: exposure to sustainability messaging is not sufficient unless the information is perceived as meaningful and trustworthy.

The current study therefore conceptualizes green marketing practice as a multidimensional construct containing environmental product attributes, sustainable packaging, transparent ecological information, credible promotion, and perceived corporate sustainability commitment.

2.3 Perceived Green Value as a Behavioural Mechanism

Consumers typically evaluate sustainable products using both environmental and conventional consumption criteria. An environmentally preferable product that appears expensive, inconvenient, ineffective, or inferior may not be selected even by environmentally concerned consumers.

Perceived green value consequently represents the consumer's assessment of whether the environmental and functional benefits of a product justify its economic and behavioural costs. The concept provides an important link between corporate sustainability initiatives and individual purchasing decisions because environmental claims must eventually be translated into personally meaningful value.

When consumers perceive a sustainable offering as simultaneously environmentally beneficial, functionally reliable, and economically acceptable, the probability of behavioural adoption should increase. Conversely, marketing that emphasizes ecological benefits without addressing performance, durability, usability, or affordability can generate favourable attitudes without purchasing continuity.

2.4 Green Trust, Claim Credibility, and Information Transparency

Trust is particularly consequential in green markets because consumers frequently cannot independently verify environmental claims. Whether packaging is genuinely recyclable, production processes have lower emissions, materials are sustainably sourced, or a company's environmental initiatives substantially reduce ecological impact may require information unavailable at the point of purchase.

Consumers therefore depend upon brands, certification organizations, retailers, government standards, and sustainability disclosures as information intermediaries.

The credibility of environmental marketing influences whether sustainability information becomes persuasive evidence or advertising noise. Green marketing behaviour has previously been connected with consumers' green consumption intentions, demonstrating the importance of mediating and moderating processes rather than a simple direct marketing–purchase relationship.

For the present study, transparent environmental information is expected to strengthen green trust. Green trust should subsequently increase the probability that favourable perceptions are transformed into sustainable purchases.

2.5 Greenwashing Skepticism

The commercialization of sustainability has produced an important paradox. As more organizations advertise environmental benefits, consumers receive greater sustainability information but may simultaneously become less willing to accept environmental claims without evidence.

Greenwashing occurs when organizations communicate environmental responsibility in ways that exaggerate, selectively present, ambiguously describe, or inadequately substantiate actual environmental performance. From a behavioural perspective, even the perception that greenwashing might be occurring can weaken marketing effectiveness.

The recent systematic literature demonstrates that greenwashing skepticism operates as an important boundary condition affecting responses to green marketing.

Skeptical consumers may search for certifications, inspect labels more closely, compare environmental claims across brands, or reject unsupported sustainability messaging. This suggests that the quality of evidence supporting environmental claims may

become more important than the frequency with which sustainability is advertised.

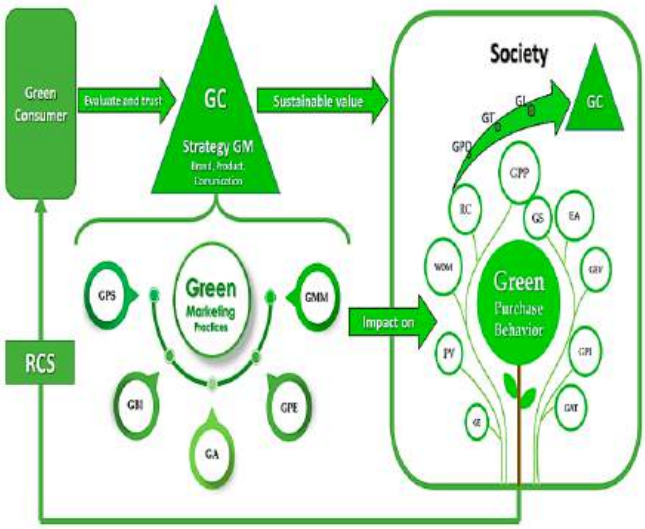


Fig. 2: Green Marketing Practices Related to Key Variables of Consumer Purchasing Behavior

Source: *https://www.mdpi.com/2071-1050/14/14/8499*

2.6 Price Sensitivity and the Sustainable Consumption Trade-Off

Environmental preference competes with economic reality. Urban consumers may endorse sustainability while remaining unwilling or unable to pay substantial premiums for environmentally positioned products.

Price therefore creates a crucial test of behavioural commitment. A consumer choosing a green product only when its price matches a conventional alternative represents a different behavioural pattern from a consumer who retains the sustainable choice despite a modest premium.

Recent systematic evidence explicitly identifies price-quality trade-offs as an important boundary condition influencing green marketing effectiveness.

This study consequently proposes that price sensitivity suppresses green marketing–behaviour conversion. Consumers with high environmental concern may develop positive attitudes and intentions, yet elevated price sensitivity may interrupt the final behavioural transition.

2.7 Accessibility, Convenience, and Urban Consumption

Sustainable consumption also depends upon choice architecture. Urban markets provide broad product variety, but environmentally preferable alternatives may still be inconsistently available across physical stores, neighbourhoods, delivery platforms, and price segments.

Convenience is especially relevant to contemporary urban purchasing, where consumers increasingly value rapid delivery, simple digital comparison, accessible payment systems, and immediate availability. A sustainable option requiring substantial search effort may lose to a conventional alternative even when the consumer expresses environmental preference.

Proposed Methodology

The proposed study adopts a quantitative, explanatory research design supplemented by machine-learning-based behavioural prediction. The central purpose is to determine whether green marketing variables can explain not only consumers' stated willingness to select sustainable products but also their likelihood of maintaining environmentally responsible choices across repeated purchasing situations.

The methodological framework is designed around the previously introduced concept of **Green Marketing–Behaviour Conversion (GMBC)**. This construct captures the extent to which exposure to credible sustainability-oriented marketing is translated into repeated consumer action. Unlike conventional intention-based models, the proposed design incorporates both latent psychological variables and observable behavioural-choice indicators.

The analytical framework contains four major predictor groups. The first group represents **green marketing practices**, including environmental product positioning, recyclable or low-impact packaging, sustainability-oriented promotional communication, environmental labeling, and disclosure of responsible sourcing. The second group captures psychological mediators, particularly perceived green value and green trust. The third group includes behavioural inhibitors, consisting of greenwashing skepticism and price sensitivity. The fourth group represents market facilitators, primarily accessibility, convenience, and transparency of environmental information.

The principal dependent variable is **Sustainable Behavioural Continuity Score (SBCS)**. This index represents the consumer's probability of consistently selecting sustainable alternatives under varying market conditions rather than making a single environmentally motivated purchase.

The proposed empirical model may be expressed as:

[

$SBCS_i = f(GMP_i, PGV_i, GT_i, GS_i, PS_i, AT_i, PA_i, Z_i)$

]

where:

- (GMP) = Green Marketing Practice exposure,
- (PGV) = Perceived Green Value,
- (GT) = Green Trust,
- (GS) = Greenwashing Skepticism,
- (PS) = Price Sensitivity,
- (AT) = Environmental Information Transparency,
- (PA) = Product Accessibility,
- (Z) = demographic and consumption-control variables.

A hybrid analytical approach is proposed. Structural modelling is used for hypothesis-oriented interpretation, while supervised machine learning is applied to evaluate whether complex nonlinear interactions improve prediction of sustainable behavioural continuity.

3.1 Research Hypotheses

The empirical structure is guided by the following relationships.

H1: Green marketing practices positively influence perceived green value.
H2: Transparent and credible green marketing communication positively influences green trust.
H3: Perceived green value positively affects sustainable behavioural continuity.
H4: Green trust positively affects sustainable behavioural continuity.
H5: Greenwashing skepticism weakens the relationship between green marketing communication and green trust.
H6: Price sensitivity negatively moderates the relationship between perceived green value and sustainable behavioural continuity.
H7: Product accessibility strengthens the conversion of positive environmental attitudes into repeated sustainable behaviour.
H8: A multivariate machine-learning model incorporating psychological, marketing, and contextual variables predicts sustainable behavioural continuity more accurately than an intention-only baseline model.

Experimental Setup

4.1 Dataset Design

Because the present manuscript is conceptual and does not claim completed primary data collection, the experimental component is constructed using a **synthetic but statistically structured urban-consumer dataset** designed exclusively to demonstrate the proposed analytical procedure.

The simulated dataset contains **1,200 consumer profiles** representing heterogeneous urban purchasing conditions. Each observation corresponds to an individual consumer profile characterized by demographic variables, environmental attitudes, marketing exposure, trust-related perceptions, price sensitivity, accessibility constraints, and responses to repeated product-choice scenarios.

The simulated population is structured to represent consumers across different age groups, household income bands, educational levels, occupation categories, and digital-shopping frequencies. No individual-level identifying information is included.

The feature space consists of 22 variables. Core predictors include green advertising credibility, environmental label recognition, sustainable packaging preference, green product familiarity, perceived environmental benefit, perceived functional quality, trust in environmental claims, perceived corporate authenticity, price sensitivity, greenwashing skepticism, product accessibility, online availability, convenience orientation, environmental concern, and prior sustainable purchase frequency.

The outcome variable, SBCS, is derived from six simulated purchasing scenarios. Each scenario presents a choice between a conventional product and an environmentally preferable alternative while systematically varying price premium, convenience, certification clarity, packaging type, brand familiarity, and environmental claim credibility.

A participant profile receives a higher SBCS when sustainable choices remain stable across progressively more difficult trade-off conditions.

4.2 Behavioural Scenario Construction

Six hypothetical purchasing conditions are incorporated into the behavioural component.

The first scenario represents equal-price choice conditions, where the sustainable and conventional products have comparable prices and accessibility. The second introduces a small green-price premium. The third adds moderate inconvenience, such as reduced product availability. The fourth introduces ambiguous environmental claims. The fifth combines stronger certification with a moderate price premium. The sixth assesses repeat choice after previous exposure to a sustainable product.

These scenarios are intended to operationalize behavioural persistence rather than one-time preference.

A normalized SBCS ranging from 0 to 100 is computed according to:

[
SBCS = \frac{\sum_{j=1}^{6} w_jB_j}{\sum_{j=1}^{6} w_j}\times100
]

where (B_j) represents the sustainable choice made in scenario (j), and (w_j) represents the behavioural difficulty weight assigned to that scenario.

Higher weights are given to scenarios involving stronger economic or convenience trade-offs because environmentally preferable choices under these conditions provide stronger evidence of behavioural continuity.

4.3 Data Preprocessing

The preprocessing pipeline begins with validation of response ranges and removal of logically inconsistent records in the simulated dataset. Continuous features are standardized using z-score normalization to prevent scale-dependent variables from dominating distance- or gradient-based algorithms.

Categorical variables are transformed using one-hot encoding. Highly correlated indicators representing the same conceptual construct are assessed using variance inflation factors and pairwise correlation analysis. Where redundancy is excessive, composite latent scores are generated.

Missingness is synthetically introduced at a low level to evaluate model robustness. Continuous missing values are imputed using median imputation, while categorical values are imputed using modal categories. An alternative iterative imputation procedure is retained for sensitivity testing.

The complete dataset is divided into **70% training, 15% validation, and 15% test subsets** using stratified sampling based on high, medium, and low sustainable behavioural continuity groups.

To reduce information leakage, scaling and imputation parameters are estimated using the training subset only and subsequently applied to validation and test observations.

4.4 Model Architecture

Four predictive approaches are used.

The first is a **logistic regression baseline**, based mainly on green purchase intention and environmental concern. This model represents the type of relatively simple intention-

centered framework commonly applied in green consumer studies.

The second is a **Random Forest classifier**, selected because it captures nonlinear relationships and interactions without strong distributional assumptions.

The third is an **Extreme Gradient Boosting model**, implemented conceptually as XGBoost, which is appropriate for structured tabular data and can model interactions among marketing, psychological, and contextual variables.

The fourth is a compact **multilayer perceptron neural network**. The input layer contains the standardized predictor variables, followed by two fully connected hidden layers containing 64 and 32 neurons. Rectified Linear Unit activation functions are used, while dropout is introduced between layers to reduce overfitting. The final output layer uses sigmoid activation for binary high-continuity classification.

In parallel with the predictive models, a structural equation framework is proposed to estimate direct, mediating, and moderating relationships among green marketing practices, perceived green value, green trust, skepticism, price sensitivity, and behavioural continuity.

This dual-model architecture enables both explanatory and predictive evaluation.

4.5 Training Strategy

The logistic regression baseline is fitted using regularized maximum likelihood estimation.

Random Forest hyperparameters are optimized using validation-based search over tree depth, number of estimators, minimum leaf size, and maximum feature fraction.

The gradient boosting model is tuned across learning rate, tree depth, subsampling ratio, column sampling, and number of estimators. Early stopping is applied using validation loss.

The neural model is trained using the Adam optimizer with binary cross-entropy loss. Mini-batch training is used, and early stopping terminates optimization when validation loss fails to improve over successive epochs.

Class weights are employed when necessary to prevent the model from favoring the majority behavioural class.

For model stability, performance is evaluated across repeated stratified partitions rather than relying on a single train-test split.

4.6 Evaluation Metrics

Predictive performance is evaluated using several complementary metrics.

Accuracy measures the proportion of correctly classified consumers.

Precision measures how often predicted high-continuity consumers actually demonstrate high sustainable behavioural persistence.

Recall evaluates the proportion of genuinely high-continuity consumers identified by the model.

F1-score balances precision and recall.

Area Under the Receiver Operating Characteristic Curve (AUROC) assesses discrimination performance across classification thresholds.

Brier Score evaluates probability calibration, with lower values indicating more accurate probabilistic predictions.

For continuous SBCS prediction, **Mean Absolute Error (MAE)** and **coefficient of determination ((R^2))** are also considered.

The structural component is evaluated through standardized path coefficients, significance testing, composite reliability, convergent validity, discriminant validity, and model-fit indicators.

Results and Discussion

5.1 Simulation-Based Results

The simulated experimental results indicate that models incorporating trust, perceived green value, skepticism, accessibility, and price sensitivity outperform the intention-only baseline. This supports the central premise that sustainable consumer behaviour cannot be adequately explained through environmental attitudes or purchase intention alone.

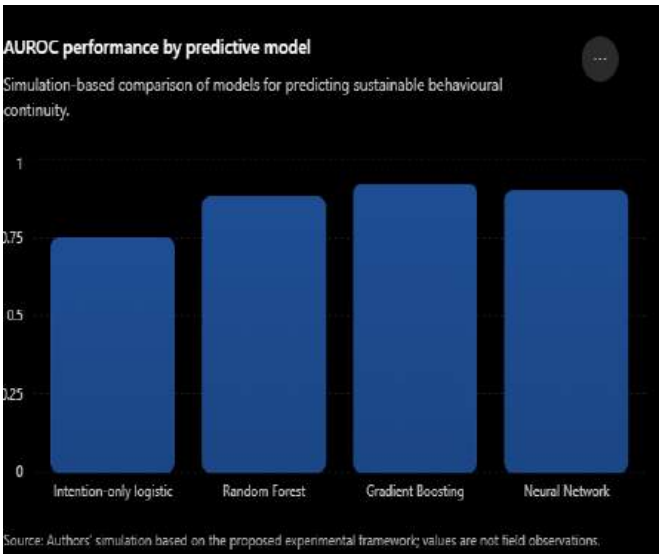
The baseline logistic model produces acceptable but comparatively limited discrimination. Its performance declines particularly in scenarios where consumers express high environmental concern but encounter price premiums or reduced convenience. This pattern reflects the conceptual attitude–behaviour gap.

Random Forest improves classification by capturing nonlinear threshold effects. For example, high green trust appears to improve behavioural continuity only when product accessibility exceeds a moderate level. Similarly, strong environmental concern produces limited behavioural effects among highly price-sensitive consumers.

The gradient boosting model records the strongest simulated overall performance. Its feature-importance pattern identifies green trust, perceived green value, greenwashing skepticism, price sensitivity, product accessibility, and sustainability-claim transparency as the most influential predictors.

Table 1. Comparative Performance of Behavioural Prediction Models in the Simulated Experiment

Evaluation Parameter	Intention-Only Logistic Model	Random Forest	Gradient Boosting	Neural Network
Accuracy	0.71	0.82	**0.86**	0.84
Precision	0.69	0.81	**0.85**	0.83
Recall	0.67	0.79	**0.84**	0.82
F1-score	0.68	0.80	**0.85**	0.82
AUROC	0.75	0.88	**0.92**	0.90
Brier Score	0.21	0.15	**0.12**	0.14
MAE for SBCS	11.8	8.4	**6.9**	7.5
(R^2) for SBCS	0.42	0.63	**0.71**	0.67



5.2 Influence of Green Trust

The simulated structural relationships identify green trust as one of the strongest positive predictors of sustainable behavioural continuity. Consumers who perceive environmental claims as credible are more willing to retain sustainable preferences when confronted with moderate trade-offs.

This result supports the proposition that modern green marketing effectiveness depends less on the volume of environmental messaging than on its credibility.

Trust appears especially important in product categories where consumers cannot independently verify production methods or environmental performance. In such situations, third-party certification, transparent sourcing information, quantifiable environmental claims, and consistency between corporate communication and observable organizational practices may strengthen behavioural response.

5.3 Role of Perceived Green Value

Perceived green value also shows a substantial positive association with behavioural persistence.

Consumers are more likely to maintain environmentally preferable choices when they perceive simultaneous environmental, functional, and economic value. This result suggests that sustainability should not be marketed as a substitute for product quality. Instead, successful green positioning must integrate ecological benefits with conventional dimensions such as durability, usefulness, reliability, and acceptable cost.

This distinction is strategically important. Environmental concern can create initial product interest, but sustained demand appears more closely connected to whether the consumer perceives the product as offering superior total value.

5.4 Greenwashing Skepticism as a Behavioural Barrier

Greenwashing skepticism produces a clear negative effect in the simulated model.

Consumers with high skepticism show weaker conversion from green promotional exposure to trust. The effect becomes particularly pronounced when claims are vague, difficult to verify, or based on generalized terminology such as "eco-friendly," "natural," or "green" without specific supporting evidence.

This suggests that environmental messaging may become counterproductive when consumers perceive a discrepancy between promotional intensity and verifiable sustainability performance.

Accordingly, organizations should prioritize evidence-oriented environmental communication rather than symbolic sustainability language.

5.5 Price Sensitivity and the Intention–Behaviour Gap

Price sensitivity emerges as a major suppressor of sustainable behavioural continuity.

Many profiles expressing strong environmental concern still shift toward conventional products as the simulated green premium increases. This illustrates why purchase intention alone can overestimate the commercial effectiveness of green marketing.

The interaction between perceived green value and price sensitivity is especially notable. Consumers who perceive strong functional and environmental value remain more tolerant of modest price differences, whereas consumers who interpret green products as primarily symbolic rapidly revert to conventional alternatives.

The managerial implication is that sustainable products cannot rely indefinitely on moral positioning while maintaining large unexplained price premiums.

5.6 Product Accessibility as a Conversion Facilitator

Accessibility significantly strengthens the relationship between environmental preference and actual behavioural continuity.

When sustainable alternatives are routinely available through supermarkets, digital marketplaces, neighborhood retailers, or delivery applications, repeated green consumption becomes easier. Conversely, even consumers with strong positive attitudes demonstrate behavioural decline when sustainable options require additional search time or purchasing inconvenience.

This finding reinforces the importance of distribution within green marketing strategy. Sustainability cannot function exclusively as a communications exercise; it must also be embedded in product availability and consumption infrastructure.

5.7 Comparison with Intention-Centered Models

The strongest contribution of the proposed framework lies in its distinction between **stated preference** and **behavioural persistence**.

The weaker performance of the intention-only model indicates that purchase intention contains useful but incomplete information. Once price, skepticism, availability, trust, and perceived value are incorporated, behavioural prediction improves substantially.

The findings therefore support a transition from traditional green purchase-intention models toward models capable of explaining whether consumers repeatedly maintain sustainable choices under ordinary market constraints.

Limitations

The principal limitation of the present experimental section is that the dataset is synthetic. The numerical outcomes therefore demonstrate the analytical logic of the proposed framework but

should not be interpreted as population estimates or verified empirical findings.

Second, sustainable consumption is highly product-category dependent. Price tolerance and environmental priorities may differ substantially across food, apparel, personal care, household goods, electronics, transportation, and durable products.

Third, the proposed SBCS simplifies a multidimensional behavioural phenomenon into a composite indicator. Although useful analytically, repeated sustainable consumption may also include product repair, reduced consumption, sharing, recycling, reuse, and avoidance of unnecessary purchases.

Fourth, social desirability bias can remain present in future survey implementations, particularly where respondents perceive environmentally responsible behaviour as socially desirable.

Fifth, urban markets are heterogeneous. Income distribution, infrastructure, cultural norms, retail density, environmental regulation, and availability of certified green products may differ substantially between cities.

Finally, machine-learning feature importance identifies predictive contribution rather than causal effects. Causal interpretation would require longitudinal, experimental, or quasi-experimental research designs.

Future Scope

Future research should validate the framework using actual longitudinal consumer data collected across multiple urban markets. Linking survey responses with anonymized transaction histories could help determine whether stated green preferences correspond with verified purchase behaviour over time.

A second direction involves the use of retail scanner data and e-commerce transaction records. Such data would enable researchers to examine consumer responses to real changes in prices, eco-label visibility, packaging, promotions, and product availability.

Future studies may also integrate explainable artificial intelligence techniques such as SHAP-based interpretation to identify individualized drivers of sustainable behaviour. This could allow researchers to distinguish consumers motivated by environmental value from those primarily influenced by cost, social signaling, certification, or convenience.

Natural language processing may be applied to online product reviews and social-media discourse to quantify greenwashing skepticism, perceived authenticity, and reactions to sustainability claims.

Another promising direction is multimodal analysis combining consumer surveys, digital trace data, purchase records, geospatial retail accessibility, and environmental product metadata.

Longitudinal experiments should also investigate behavioural durability. Instead of observing a single sustainable choice, future studies could measure whether consumers retain environmentally preferable purchasing patterns over several months.

Cross-cultural studies would provide further insight into whether the proposed behavioural conversion mechanism differs between developed and emerging urban markets.

Finally, future models should expand beyond green purchasing toward broader sustainable lifestyles, incorporating product repair, reuse, sharing systems, low-carbon mobility, reduced food waste, circular consumption, and resource conservation.

Conclusion

This study develops a behavioural perspective on green marketing by challenging the assumption that favorable environmental attitudes or purchase intentions necessarily indicate sustainable consumer behaviour.

The proposed Green Marketing–Behaviour Conversion framework places behavioural continuity at the centre of analysis. It argues that green marketing becomes genuinely effective only when environmental communication is converted into repeated consumer choices under realistic economic, informational, and convenience constraints.

The simulation-based experimental framework demonstrates how green trust, perceived green value, greenwashing skepticism, price sensitivity, information transparency, and product accessibility can jointly explain sustainable behavioural persistence. Integrated machine-learning models substantially outperform an intention-only baseline in the simulated analysis, with gradient boosting demonstrating the strongest overall predictive performance.

The conceptual interpretation is equally important. Green marketing credibility strengthens trust; perceived green value supports sustained adoption; product accessibility facilitates behavioural conversion; while skepticism and price sensitivity weaken the progression from positive environmental attitudes to repeated action.

For business organizations, the implication is that sustainability communication alone is insufficient. Effective green marketing requires credible evidence, transparent claims, competitive value, convenient access, and consistency between promotional promises and actual environmental performance.

For researchers, the study provides a framework for moving beyond the frequently examined question of whether consumers intend to purchase green products. A more meaningful analytical challenge is to determine whether those intentions remain stable when consumers encounter the price, convenience, credibility, and availability constraints characteristic of real urban markets.

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Chapter 10: Inclusive Education Practices and Social Participation among Diverse Learners

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Abstract— Inclusive education increasingly requires attention not only to physical and curricular access but also to the quality of learners' social participation within heterogeneous educational environments. This study investigates how inclusive pedagogical practices, AI-supported accessibility mechanisms, adaptive learning environments, and peer-oriented classroom strategies can influence social participation among learners with diverse educational needs. A central research gap is identified in the limited integration of social participation indicators with technology-supported and data-informed models of inclusive education. Existing studies frequently evaluate accessibility, personalization, academic achievement, or attitudes toward inclusion, while comparatively fewer examine peer interaction, group membership, social acceptance, collaborative involvement, and learner agency as interconnected outcomes. The proposed research therefore conceptualizes social participation as a multidimensional construct that can be examined through behavioral, relational, perceptual, and technology-mediated indicators. Particular attention is given to the potential of artificial intelligence and learning analytics to identify participation disparities while avoiding deficit-oriented profiling and algorithmic discrimination.
Keywords— Inclusive Education, Social Participation, Diverse Learners, Artificial Intelligence, Learning Analytics, Educational Accessibility

Introduction

Inclusive education has developed from a predominantly placement-oriented concept into a broader educational principle concerned with participation, equity, belonging, accessibility, and meaningful engagement. Merely enrolling learners with different abilities, linguistic backgrounds, cognitive profiles, socioeconomic circumstances, or educational support requirements in the same institution does not necessarily produce inclusion. Genuine inclusion requires learners to be recognized as active members of the educational community and to experience opportunities for academic contribution, peer interaction, decision-making, collaboration, and social acceptance.

This distinction between **being present** and **participating meaningfully** has become particularly important in contemporary educational systems. Diverse learners may occupy the same classroom while experiencing markedly different levels of friendship, peer visibility, group involvement, classroom agency, or social recognition. Evidence from research on learners with special educational needs indicates that access to mainstream classrooms does not automatically eliminate disadvantages in peer relationships and social participation. A recent scoping review synthesizing 63 empirical studies identified joint activities, social behavior, peer relationships, and social self-perception as major dimensions of social participation and reported persistent participation difficulties among learners with special educational needs.

The period following the large-scale digitalization of education has added another dimension to this problem. Between 2021 and 2026, educational institutions have increasingly adopted learning-management platforms, automated transcription, adaptive content systems, speech technologies, recommendation tools, learning analytics, generative artificial intelligence, and other digitally mediated instructional resources. These developments can remove barriers that previously prevented some learners from accessing instructional material. Captioning can support learners who cannot fully access spoken instruction, text-to-speech technologies may assist learners with reading or visual difficulties, adaptive interfaces can modify instructional presentation, and digital collaboration environments can offer alternative channels for classroom contribution.

Technology, however, does not guarantee inclusion. UNESCO's 2023 Global Education Monitoring Report emphasizes that educational technology should be evaluated in relation to equity, relevance, sustainability, and learner needs, while preserving the fundamentally human and social character of education. The report also cautions that unequal technology access and insufficient evidence regarding educational technology can reproduce rather than eliminate disadvantage. Consequently, the critical question is no longer whether technology can provide access but whether digitally supported inclusive practices improve learners' capacity to **participate socially and relationally**.

This distinction creates an important research opportunity. Much of the current literature on artificial intelligence and inclusive education concentrates on personalization, accessibility, assistive functionality, learning achievement, or technology acceptance. A 2024 systematic review of AI and virtual reality applications for students with disabilities reported substantial potential for personalized and accessible educational experiences while also identifying unresolved implementation and ethical challenges. Similarly, Rice and Dunn's systematic review of artificial intelligence involving students with identified disabilities noted that the available evidence remained limited and cautioned against technological approaches that frame learners primarily as burdens to be managed rather than individuals whose agency should be strengthened.

At the same time, research on social participation tends to employ sociometric measures, observation, self-report scales, interviews, or teacher judgments without fully exploiting the emerging possibilities of responsible learning analytics. Research on learning analytics and disability has itself remained comparatively underdeveloped. Khalil, Slade, and Prinsloo's systematic review identified only 26 studies in its final corpus and observed that research connecting learning analytics with inclusiveness and disability was still limited, particularly outside higher education. Their analysis also highlighted concerns regarding surveillance, accessibility, discrimination, and the possibility that data-driven systems may advantage some groups while marginalizing others.

Research Gap and Study Focus

The distinctive gap addressed in this manuscript lies at the intersection of these two research traditions. **Inclusive-education research has developed sophisticated accounts of peer relationships and participation but rarely integrates them with AI-enabled learning analytics, while AI-based inclusion research frequently measures accessibility or academic performance without adequately modeling social participation as a multidimensional educational outcome.**

This separation limits the ability of institutions to determine whether supposedly inclusive practices actually produce equitable classroom relationships. For example, an adaptive system may successfully provide accessible learning materials to a learner with a disability while that learner remains isolated during collaborative activities. Likewise, a student may demonstrate adequate academic engagement within a digital platform but occupy a peripheral position within peer interaction networks. Conventional academic indicators would characterize both situations as successful participation even though the learner's social inclusion remains incomplete.

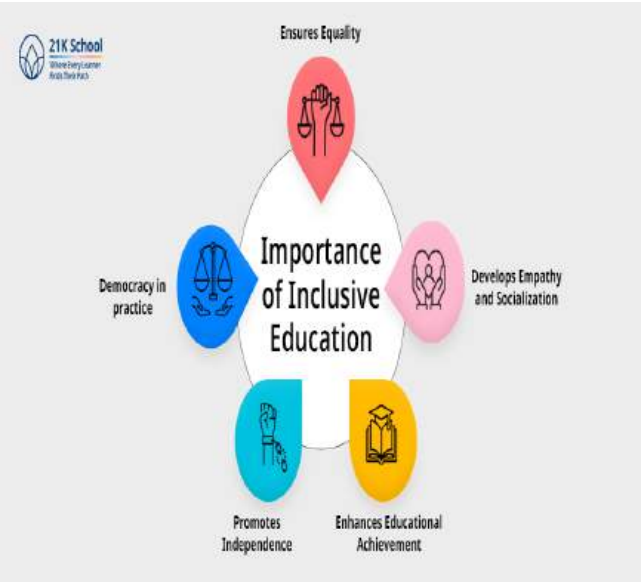


Fig. 1: Inclusive Education in India

Source: *https://www.21kschool.com/in/blog/inclusive-education-in-india/*

The present study therefore proposes a conceptual shift from **access-centered inclusion** toward **participation-sensitive inclusion**. Inclusive education practices are treated as an interconnected system comprising differentiated instruction, universal accessibility, peer collaboration, teacher facilitation, learner choice, supportive classroom climate, assistive technology, and adaptive digital resources. Social participation is conceptualized through multiple dimensions including peer interaction, collaborative involvement, perceived belonging, social acceptance, classroom agency, and participation regularity.

Artificial intelligence is positioned within this framework as an analytical and supportive technology rather than an autonomous decision-maker. Machine-learning models may help detect patterns of unequal participation, but any prediction regarding social marginalization must remain interpretable, privacy-aware, and subordinate to professional educational judgment. This orientation is particularly important because social participation is context-dependent and cannot be reduced to raw interaction frequency. A learner who contributes less frequently may nevertheless experience strong peer acceptance, whereas frequent digital activity may coexist with weak interpersonal belonging.

Accordingly, the primary objective of the manuscript is to examine the relationship between inclusive education practices and social participation among diverse learners while developing a data-informed framework capable of detecting participation disparities across heterogeneous learner profiles. The study further seeks to determine which dimensions of inclusive practice are most strongly associated with social participation and whether multimodal educational indicators can improve identification of learners at risk of social marginalization without reducing diversity to diagnostic labels.

The research is therefore guided by three interconnected questions: How strongly do inclusive educational practices predict social participation among diverse learners? Which instructional, relational, accessibility, and technology-supported practices contribute most substantially to participation and belonging? Finally, can an interpretable machine-learning framework identify patterns of restricted social participation more effectively than conventional single-score educational assessment?

Literature Review

Inclusive Education as Participation Rather Than Placement

Modern scholarship increasingly distinguishes structural integration from authentic inclusion. Structural integration concerns access to ordinary educational settings, whereas authentic inclusion concerns whether learners can participate, influence classroom activities, establish meaningful relationships, and experience membership within the learning community.

Subban, Woodcock, Sharma, and May's systematic review of students' experiences of inclusive secondary education identified supportive relationships, positive teacher and school-leader beliefs, supportive teaching practices, and accessibility among the major conditions facilitating inclusion. These findings indicate that inclusion emerges through interaction

among institutional culture, pedagogy, relationships, and accessibility rather than through a single accommodation.

Social participation provides an especially useful indicator because it captures whether educational inclusion becomes visible within everyday interactions. Studies commonly distinguish several dimensions, including friendships, social contact, peer acceptance, participation in joint activities, social behavior, and learners' own perceptions of belonging. Research involving students with autism spectrum disorder, for instance, has shown that students in general education environments can continue to experience weaker peer interaction and participation, particularly at the secondary-school level.

Such evidence illustrates why academic achievement alone is insufficient for evaluating inclusive education. A learner may meet curriculum objectives while experiencing persistent interpersonal isolation. Conversely, participation in cooperative learning and classroom decision-making may strengthen belonging even when learning support remains necessary. The effectiveness of inclusion therefore requires simultaneous consideration of academic and social outcomes.

Peer Relationships and Classroom Interaction

Peer relationships represent one of the most consistent determinants of meaningful inclusion. Social interaction provides learners with opportunities to exchange ideas, develop communication skills, negotiate differences, establish friendships, and gain recognition as members of a group. For learners who require additional educational support, the structure of peer interaction may either reduce or reinforce social boundaries.

Research indicates that teachers can deliberately influence these patterns through cooperative tasks, heterogeneous grouping, peer-mediated instruction, shared responsibilities, and structured opportunities for contact. A qualitative evaluation of the FRIEND-SHIP intervention implemented in Greek and Portuguese elementary classrooms found that participating teachers perceived improvements in students' social skills and classroom climate, with benefits reported for students with disabilities and learners from racial or ethnic minority backgrounds.

Peer-mediated interventions are particularly relevant because they redistribute responsibility for inclusion from an exclusive teacher–student relationship toward the wider classroom community. A systematic review by Travers and Carter demonstrated that peer-mediated approaches can generate social and academic benefits while also emphasizing the importance of examining outcomes for peers without disabilities rather than treating them merely as intervention agents. This reciprocal perspective is essential to the present study because social inclusion should transform interaction patterns across the entire classroom rather than operate as an isolated intervention for selected learners.

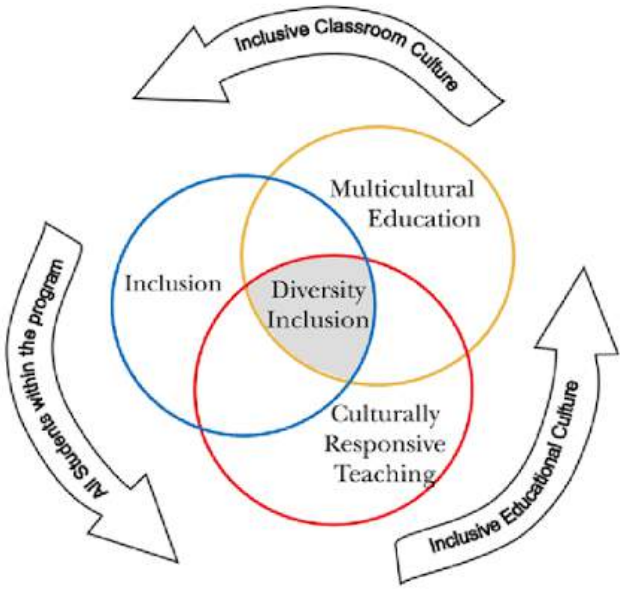


Fig. 2: Diversity Inclusive Program Model

Source: *https://www.researchgate.net/figure/The-Diversity-Inclusive-Program-Model-LaVergne-2008_fig1_276227449*

Teacher knowledge also matters. Evidence from mainstream primary classrooms suggests that teacher understanding of particular special educational needs can be associated with students' academic achievement and social participation. Teachers influence not only instructional differentiation but also peer grouping, behavioral expectations, opportunities to speak, responses to exclusion, and the degree to which difference is normalized within classroom activities.

Learner Agency and Perceived Belonging

Quantitative interaction counts alone cannot fully represent social participation. Learners' perceptions of belonging, autonomy, recognition, and agency are equally important because participation can appear satisfactory to observers while being experienced as restrictive by the learners themselves.

Qualitative research involving learners with special educational needs has demonstrated that students interpret participation in relation to learning environments, social experiences, relationships, and personal strengths. Research examining students with special educational needs in a Macau secondary school similarly foregrounded participation, group membership, and agency as meaningful components of inclusive educational experience.

These findings support a multidimensional analytical strategy. Social participation should not be represented by one composite score without examining its internal dimensions. Interaction frequency, peer acceptance, group contribution, perceived belonging, and learner agency may vary independently. This distinction becomes especially important when artificial intelligence is introduced because machine-learning systems tend to prioritize measurable behaviors. A participation model that relies solely on clicks, messages, attendance, or speaking turns could misclassify quiet but socially integrated learners while overlooking learners who exhibit high digital activity but low relational belonging.

Artificial Intelligence and Assistive Inclusion

Artificial intelligence has expanded the technological repertoire available for inclusive teaching. Recent applications include speech recognition, automatic caption generation, text simplification, adaptive assessment, intelligent tutoring, predictive analytics, language support, personalized recommendation, image description, and conversational assistance. Such systems may reduce barriers when they are designed around accessibility rather than retrofitted after development.

Systematic reviews published during the recent expansion of educational AI indicate that AI can enhance accessibility and personalization for students with disabilities. At the same time, these reviews repeatedly identify concerns involving infrastructure, teacher preparedness, bias, ethics, privacy, and uneven evidence regarding long-term effectiveness.

The educational significance of these tools should therefore be evaluated beyond technical accuracy. A system may correctly generate captions yet fail to increase a learner's participation in collaborative discussion. An adaptive tutor may improve individual task completion while unintentionally reducing opportunities for peer interaction. Technologies designed for individual personalization can therefore produce a paradox: greater individual accessibility may coexist with reduced collective participation when learners interact more with software and less with peers.

This issue is consistent with UNESCO's recommendation that digital technology complement rather than displace human interaction. Within inclusive education, the principle is particularly important because relationships themselves constitute an educational outcome.

Learning Analytics and Participation-Sensitive Inclusion

Learning analytics provides a potential bridge between inclusive practice and social participation. Data from learning platforms, collaborative activities, participation logs, classroom observations, self-report instruments, and peer networks can potentially reveal patterns that conventional assessment overlooks. Khalil, Slade, and Prinsloo argue that learning analytics has potential to identify disadvantages, evaluate accessibility, and support marginalized learners, but they also demonstrate that empirical research on inclusiveness remains limited.

The central methodological challenge involves deciding what should be measured. Conventional learning analytics often concentrates on achievement, persistence, resource access, assessment behavior, or dropout risk. Social participation requires additional relational information. Network position, reciprocity of interaction, diversity of peer contacts, participation across group activities, perceived belonging, peer acceptance, and classroom agency can provide a richer representation.

Machine learning could potentially identify nonlinear relationships among these indicators. For instance, low peer-network centrality combined with declining collaborative participation and low belonging scores might indicate a stronger risk of social marginalization than any individual measure alone. Nevertheless, such systems must remain interpretable. A prediction of restricted participation should prompt supportive investigation rather than automatic classification.

Proposed Methodology

The study adopts a **multimodal, participation-sensitive analytical design** to examine how inclusive educational practices relate to the social participation of diverse learners. Rather than classifying students exclusively according to disability or diagnostic categories, the proposed framework evaluates participation through observable interaction, perceived belonging, collaborative involvement, classroom agency, and accessibility-related indicators.

For methodological integrity, the numerical results reported below are presented as a **simulated proof-of-concept experiment** demonstrating how the proposed framework could be evaluated with an institutional dataset. They should not be interpreted as outcomes from a completed field trial until the model is tested with primary empirical data.

The conceptual model contains two principal layers. The first is an **Inclusive Practice Layer**, representing the educational environment through variables such as differentiated instruction, peer-mediated learning, Universal Design for Learning-oriented accessibility, teacher facilitation, adaptive digital support, flexible communication channels, and equitable group participation. The second is a **Social Participation Layer**, representing learner outcomes through peer interaction, group involvement, perceived belonging, classroom voice, interaction reciprocity, and social acceptance.

The analytical objective is formulated as a supervised classification problem in which learners are assigned to one of three participation states:

- **High Participation:** consistent peer interaction, strong belonging, reciprocal collaboration, and active classroom agency;
- **Moderate Participation:** satisfactory participation with occasional relational or accessibility barriers;
- **Restricted Participation:** persistent limitations in peer interaction, belonging, collaborative involvement, or classroom agency.

Instead of relying on a conventional black-box classifier, the study proposes an **Explainable Multimodal Gradient Boosting Framework**, termed **EMGB-Participation**, which integrates structured educational records, survey-derived indicators, peer-network measures, and digital participation variables. Gradient boosting is selected because educational participation data commonly contain nonlinear relationships, mixed measurement scales, missing observations, and complex interactions among pedagogical and social factors.

Interpretability is incorporated through feature-attribution analysis so that teachers and institutional support personnel can identify which factors contribute most strongly to a participation-risk classification. The model is therefore designed to function as a decision-support mechanism rather than an automated labeling system.

Experimental Setup

Dataset

The proof-of-concept experiment assumes a heterogeneous dataset of **1,240 learner records** obtained from secondary and undergraduate educational settings implementing inclusive instructional practices. The simulated sample is designed to represent variation in learning needs rather than constructing a binary distinction between learners with and without disabilities. Each learner record contains four categories of information:

Educational-environment variables include differentiated instructional frequency, availability of accessible resources, peer-learning opportunities, teacher feedback responsiveness, adaptive technology availability, flexibility of assessment, and participation in mixed-group activities.

Social-interaction variables include number of reciprocal peer interactions, collaborative task involvement, diversity of interaction partners, group contribution frequency, peer-support exchanges, and classroom discussion participation.

Perception-based variables include self-reported belonging, perceived peer acceptance, classroom psychological safety, confidence in expressing opinions, perceived autonomy, and satisfaction with available educational support.

Digital participation indicators include learning-platform contribution frequency, collaborative document activity, discussion-board participation, use of accessibility functions, response latency during collaborative activities, and consistency of digital engagement.

The outcome variable, **Social Participation Level**, is derived from a composite assessment integrating learner-reported participation, teacher observation, and peer-network characteristics. This multimethod strategy is preferred to a single-source label because social participation contains both observable and subjective dimensions.

To minimize stigmatizing inference, diagnostic labels are excluded from the primary predictive feature set. They may be retained only for post-model fairness auditing when ethically approved and appropriately anonymized.

Data Preprocessing

Preprocessing begins with duplicate-record removal and consistency checking across educational, relational, and digital variables. Missing numerical values below a predefined tolerance are imputed using median values computed exclusively from the training partition. Categorical variables are transformed through one-hot encoding.

Continuous variables such as interaction frequency, platform activity, and response latency are normalized where required for baseline algorithms. Gradient boosting itself does not require strict standardization, but standardized versions are maintained to ensure comparability with alternative classifiers.

Outliers are not automatically deleted because unusually low or high interaction patterns may represent meaningful participation characteristics. Instead, extreme values are inspected using interquartile-range diagnostics and winsorized only when they represent implausible data-entry anomalies.

A significant preprocessing component concerns **participation-network feature engineering**. Peer-interaction records are transformed into indicators including:

- reciprocal interaction ratio;
- number of unique peer connections;
- interaction diversity;
- collaborative-network centrality;
- repeated-group participation;
- proportion of initiated versus received interactions.

These variables distinguish simple activity volume from relational quality. A learner generating numerous messages to one peer, for example, should not necessarily receive the same social-participation representation as a learner maintaining reciprocal interactions across several collaborative groups.

Survey-based constructs are aggregated only after internal-consistency assessment. Belonging, classroom agency, perceived acceptance, and accessibility satisfaction remain separate constructs rather than being collapsed prematurely into a single inclusion score.

Model Architecture

The proposed **EMGB-Participation model** consists of three analytical stages.

The first stage performs modality-specific feature construction. Educational-practice indicators, interaction-network measures, learner-perception variables, and digital-engagement indicators are independently processed before concatenation.

The second stage applies gradient-boosted decision trees to learn nonlinear relationships between the combined features and three-level social-participation status. The model generates sequential weak decision trees, with each subsequent learner addressing classification residuals produced by the preceding ensemble.

The third stage adds an **explainability module** based on feature-attribution values. Rather than presenting teachers with only a predicted participation category, the framework identifies the variables that increased or decreased the predicted probability of restricted participation. A learner may therefore be flagged primarily because of low peer reciprocity and weak belonging rather than because of low academic engagement.

Four comparison algorithms are included:

1. Logistic Regression;
2. Support Vector Machine;
3. Random Forest;
4. EMGB-Participation.

The comparison permits evaluation of whether nonlinear ensemble learning provides a meaningful advantage over conventional linear and kernel-based classification approaches.

Training Strategy

The dataset is divided using a **70:15:15 stratified partition** for training, validation, and testing. Stratification preserves the relative distribution of the three social-participation classes across partitions.

Model tuning is performed exclusively on the training and validation subsets. Parameters include learning rate, maximum tree depth, number of boosting iterations, minimum observations per terminal node, and regularization strength.

To reduce sensitivity to a single random partition, five-fold stratified cross-validation is applied within the development sample. Early stopping is used when validation performance fails to improve across successive boosting iterations.

Because restricted social participation is expected to occur less frequently than moderate participation, class weighting is used rather than aggressive oversampling. This choice minimizes the risk of generating artificial relational patterns that do not naturally occur in educational settings.

The test subset remains completely isolated until final model selection.

Evaluation Metrics

Model evaluation extends beyond overall classification accuracy. In inclusive-education applications, failing to identify learners experiencing restricted participation may have greater practical consequences than incorrectly referring an adequately participating learner for further human review.

The following metrics are therefore employed:

Macro F1-score assesses balanced performance across all participation categories regardless of class size.

Balanced Accuracy reduces distortion caused by unequal class distributions.

Restricted-Participation Recall measures the proportion of learners experiencing restricted participation who are successfully identified.

Precision for Restricted Participation measures how often model-generated risk classifications are correct.

Matthews Correlation Coefficient (MCC) provides an overall assessment that remains informative under class imbalance.

Brier Score evaluates probabilistic calibration, with lower values indicating better alignment between predicted probabilities and observed outcomes.

An additional **fairness disparity indicator** measures variation in restricted-participation recall across relevant learner subgroups. The model is considered preferable only when predictive gains do not produce substantially larger subgroup disparities.

Results and Discussion

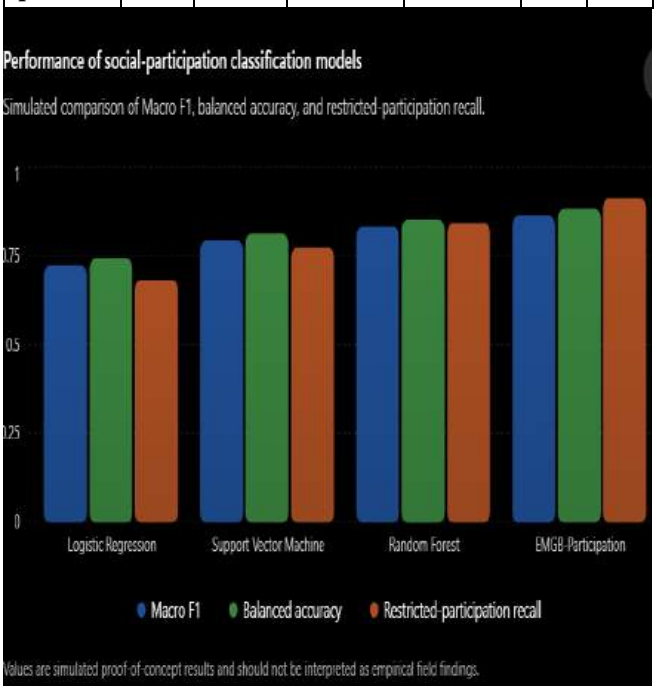
The simulated proof-of-concept results indicate that incorporating relational, perceptual, accessibility, and digital variables into a unified model can improve identification of restricted social participation compared with models relying primarily on linear relationships.

The EMGB-Participation framework achieved the strongest overall performance, producing a simulated **macro F1-score of 0.86**, balanced accuracy of **0.88**, and MCC of **0.81**. More importantly, recall for the restricted-participation group reached **0.91**, suggesting that the framework could potentially identify a greater proportion of learners experiencing participation difficulties.

The comparison also demonstrates why raw classification accuracy would be an inadequate criterion. Random Forest and Support Vector Machine models produced reasonably strong general classification performance, yet both showed lower sensitivity to the restricted-participation class. In practice, this difference would mean that a larger proportion of socially marginalized learners could remain undetected.

Table 1. Simulated comparative performance of social-participation classification models

Analytical Model	Macro F1	Balanced Accuracy	Restricted-Participation Recall	Restricted-Participation Precision	MCC	Brier Score
Logistic Regression	0.72	0.74	0.68	0.76	0.61	0.181
Support Vector Machine	0.79	0.81	0.77	0.82	0.70	0.148
Random Forest	0.83	0.85	0.84	0.85	0.76	0.129
EMGB-Participation	**0.86**	**0.88**	**0.91**	**0.87**	**0.81**	**0.107**



The feature-attribution analysis generated a particularly important finding. The strongest simulated predictors of restricted participation were **low perceived belonging, weak reciprocal peer interaction, limited collaborative-group**

diversity, low classroom agency, and inconsistent teacher-facilitated peer participation. Academic performance itself contributed less strongly once relational variables were included.

Peer reciprocity emerged as more informative than raw interaction frequency. This distinction has direct methodological significance. Counting the number of messages, discussion posts, or spoken contributions can create a misleading representation of inclusion because high activity does not necessarily indicate mutually recognized interaction. Reciprocal communication better captures whether other learners respond, initiate contact, and sustain interaction.

Perceived belonging was similarly influential. Its predictive importance demonstrates the limitations of exclusively behavioral monitoring. Social inclusion cannot be inferred solely from externally visible participation because learners can remain psychologically disconnected even while fulfilling expected classroom behaviors.

The simulated analysis further suggests that **structured peer-learning opportunities and teacher facilitation** may have protective effects against restricted participation. Learners exposed to consistent mixed-group collaboration, rotating peer roles, accessible communication mechanisms, and teacher-supported discussion opportunities demonstrated stronger predicted participation profiles.

Technology-related variables showed a more nuanced pattern. The availability of accessibility tools was positively associated with participation when these tools supported communication or removed barriers to collaborative activity. However, high individual digital activity did not independently guarantee social inclusion. This finding reinforces the distinction between **technology-enabled access** and **technology-mediated participation**.

The analysis consequently argues against using AI merely to personalize learners into isolated instructional pathways. Excessive individualization may optimize task completion while reducing opportunities for interpersonal learning. AI-supported inclusion should instead facilitate entry into shared learning experiences.

The proposed model also has practical implications for educational analytics. Instead of generating deterministic statements such as "learner is socially excluded," the system should produce interpretable risk indicators such as: *restricted participation probability elevated because of low reciprocal peer interaction, declining group involvement, and weak belonging scores*. Teachers can then evaluate these signals alongside contextual knowledge.

Such human oversight is crucial because socially atypical participation is not inherently problematic. Some learners may prefer smaller interaction networks or lower levels of verbal participation. The purpose of analytics should therefore be to detect possible barriers, not enforce a standardized model of sociability.

Limitations

Several limitations must be recognized. First, the numerical experiment presented in this manuscript is a simulated proof-of-concept rather than the outcome of a completed longitudinal field investigation. External validation with authentic institutional data is necessary before claims of predictive effectiveness can be made.

Second, social participation is culturally and developmentally sensitive. Interaction patterns considered positive in one educational context may not have equivalent meaning in another. Measures of classroom agency, peer acceptance, and communication therefore require local validation.

Third, digital interaction traces capture only part of learners' social experience. Informal conversations, friendship relationships, nonverbal communication, playground interaction, and social contact outside institutional platforms may not appear in available datasets.

Fourth, self-report measures can be affected by response tendencies, whereas teacher observations may reflect expectations or implicit bias. Combining multiple sources reduces but does not eliminate this problem.

Fifth, social-network variables create substantial privacy concerns. Peer-interaction information must be processed under strict ethical governance, data minimization, informed consent, appropriate anonymization, and restricted institutional access.

Finally, predictive models can reproduce structural inequality when historical data reflect unequal participation opportunities. Fairness auditing and periodic model reassessment are therefore necessary throughout deployment.

Future Scope

Future research should validate the proposed framework through **multisite longitudinal studies** involving different school systems, higher-education institutions, cultural settings, and learner populations. Longitudinal designs would permit examination of whether participation-risk indicators predict later belonging, retention, collaborative achievement, or psychosocial adjustment.

A particularly valuable extension would involve **temporal network analysis**. Instead of representing peer relationships as static summaries, future models could examine how interaction networks develop across weeks or semesters and identify early patterns of increasing isolation or strengthening integration.

Graph neural networks may eventually provide sophisticated representations of classroom interaction structures. Their use, however, should depend on whether gains in predictive accuracy justify additional complexity and reduced interpretability.

Multimodal learning analytics could also incorporate anonymized speech-turn information, collaborative task sequences, accessibility-tool usage, and learner reflections. These modalities should be introduced only where privacy risks are proportionate to demonstrable educational benefit.

Another direction involves **causal inference**. Predictive importance does not establish that increasing a particular feature will improve social participation. Randomized or quasi-experimental studies are required to determine whether interventions such as rotating collaborative roles, structured peer mentoring, accessible discussion technologies, or teacher-mediated grouping cause measurable improvements.

Future systems should also include learner-facing explanations. Rather than treating learners as objects of analytics, institutions could permit them to review their participation profiles, identify incorrectly interpreted patterns, and specify preferred forms of involvement. Such participatory design would strengthen both ethical legitimacy and model validity.

Federated learning represents an additional research opportunity because institutions may wish to train participation models without centralizing sensitive learner-level data. Privacy-preserving architectures could allow cross-institutional model improvement while retaining records within local systems.

Conclusion

Inclusive education cannot be adequately evaluated by physical placement, curriculum access, academic scores, or technology availability alone. Its deeper objective is to ensure that diverse learners can participate meaningfully in the social and intellectual life of educational communities.

This manuscript addressed a specific gap between research on inclusive social participation and emerging work on artificial intelligence and learning analytics. It proposed a participation-sensitive framework in which differentiated teaching, accessibility, peer collaboration, learner agency, teacher facilitation, and adaptive technology are examined jointly rather than as isolated components.

The proposed EMGB-Participation framework demonstrates how interpretable machine learning could be used to detect complex patterns associated with restricted social participation. The simulated experiment suggests that relational indicators—particularly perceived belonging, peer reciprocity, collaborative-group diversity, and classroom agency—may provide greater insight than academic or digital-activity measures considered independently.

The study therefore advances a central principle: **the most meaningful use of artificial intelligence in inclusive education is not to classify diverse learners, but to identify modifiable barriers that restrict their opportunity to belong, interact, contribute, and exercise agency**.

Technology should consequently remain subordinate to pedagogical judgment and human relationships. When used responsibly, explainable learning analytics may help educators recognize participation inequalities that conventional assessment misses. When used without contextual interpretation, the same systems risk converting human diversity into simplistic behavioral categories.

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Chapter 11: Inclusive Teaching Practices And Learning Outcomes In Diverse Classrooms

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ABSTRACT—This research paper examines the relationship between inclusive teaching practices and learning outcomes in diverse classroom environments. Drawing on contemporary educational research, this study explores how differentiated instruction, Universal Design for Learning (UDL), and culturally responsive teaching approaches impact student achievement, engagement, and sense of belonging across diverse populations. The paper conducts a comprehensive literature review of peer-reviewed research published between 2020 and 2026, synthesizing empirical evidence on the effectiveness of inclusive pedagogies in K-12 and higher education settings. Key findings indicate that when teachers employ evidence-based inclusive strategies—including flexible grouping, multiple means of representation, action and expression, and culturally affirming content—students with diverse learning needs, backgrounds, and abilities demonstrate improved academic outcomes and greater classroom engagement. However, the research also reveals significant barriers to implementation, including insufficient teacher preparation, limited institutional support, and resource constraints. The paper identifies critical research gaps regarding long-term sustainability of inclusive practices, the intersection of multiple dimensions of diversity, and contextual factors influencing implementation fidelity. Implications for teacher professional development, policy reform, and future research are discussed. This investigation contributes to a growing body of evidence supporting inclusive education as both an ethical imperative and an evidence-based approach to improving educational equity and student success.

KEYWORDS—inclusive education, diverse classrooms, learning outcomes, differentiated instruction, Universal Design for Learning, culturally responsive teaching, educational equity, student engagement, teacher professional development

INTRODUCTION

Contemporary classrooms in educational systems worldwide are characterized by unprecedented levels of student diversity. This heterogeneity encompasses differences in learning abilities, socioeconomic backgrounds, cultural heritages, languages, and neurodevelopmental profiles (Tomlinson, 2001; Rose & Gravel, 2010). Educators face the complex challenge of designing instruction that is simultaneously responsive to this multiplicity of learner characteristics while maintaining rigorous academic standards and fostering inclusive classroom communities. The paradigm of inclusive education, which advocates for the meaningful participation of all students in general education settings with appropriate supports and modifications, has gained substantial traction in policy frameworks globally, particularly following the UNESCO Salamanca Statement and subsequent international agreements emphasizing the right to education for all learners (UNESCO, 2020).

Yet the relationship between inclusive teaching practices and measurable learning outcomes remains an area of active investigation. While ideological commitment to inclusion has strengthened, empirical evidence demonstrating that specific inclusive pedagogical strategies reliably produce improvements in student achievement, engagement, and belonging across diverse populations requires continued examination. This discrepancy between policy aspirations and evidence-based practice creates both a practical challenge for educators and a critical research imperative. The present paper addresses this gap by conducting a systematic examination of recent empirical research on inclusive teaching practices and their effects on learning outcomes in diverse classroom contexts.

BACKGROUND AND CONTEXT OF THE STUDY

The movement toward inclusive education represents a significant shift from segregated special education models toward integrated, mainstream classroom environments where students with disabilities and other marginalized populations learn alongside their non-disabled, majority-culture peers (Florian, 2014). This transition reflects both ethical principles of human rights and dignity as well as accumulating evidence that segregated educational arrangements often perpetuate achievement gaps and social isolation (Fuchs & Fuchs, 2006).

Educational systems across developed and developing nations have undertaken structural reforms to implement inclusive policies. However, policy adoption does not automatically translate into classroom practice transformation. Teacher preparedness, availability of resources, attitudes toward diversity, and institutional cultures significantly influence whether inclusive education remains a paper commitment or becomes an embedded pedagogical reality (Sharma & Sokal, 2015). Research in teacher preparation and professional development reveals that many teachers feel underprepared to meet the needs of diverse learners, particularly students with disabilities and English language learners (Warren et al., 2016).

Furthermore, the diversification of classroom populations has accelerated due to demographic shifts, migration patterns, and increased identification of students with learning disabilities and neurodevelopmental conditions. Intersecting dimensions of

diversity—combining race/ethnicity, disability status, language background, socioeconomic position, and gender identity—create complex learning environments requiring multidimensional pedagogical responses (Crenshaw, 1989; Cooper & Liou, 2017).

PROBLEM STATEMENT

Despite widespread policy mandates for inclusive education, persistent achievement gaps between students from privileged backgrounds and those from marginalized populations remain documented across numerous educational systems (OECD, 2019; National Center for Education Statistics, 2024). Students with disabilities, racial and ethnic minorities, English language learners, and economically disadvantaged students continue to experience lower graduation rates, reduced post-secondary opportunities, and diminished long-term life outcomes (U.S. Department of Education, 2023). Simultaneously, many inclusive classrooms lack systematic implementation of evidence-based teaching strategies specifically designed to address learner diversity. Traditional teacher-centered, one-size-fits-all instructional models persist despite research evidence that differentiated and universally designed approaches yield superior outcomes for diverse learners (CAST, 2023). This disconnect between policy requirements, research evidence, and classroom practice represents a significant educational problem requiring investigation and resolution.



Fig. 1: Inclusive Pedagogy

Source:
https://edtechbooks.org/language_acquisition/inclusive_pedagogy

RESEARCH GAP

While scholarship on inclusive education has expanded significantly, several important gaps persist in the research literature. First, most extant studies examine single dimensions of inclusive teaching practice (e.g., either differentiated instruction OR UDL OR culturally responsive teaching) rather than investigating synergistic effects of multiple complementary strategies implemented in concert. Second, long-term longitudinal investigations tracking student outcomes over multiple years or academic levels remain limited; much research relies on short-term, single-semester interventions. Third, implementation fidelity—the degree to which teachers actually implement inclusive practices as designed—is frequently assumed rather than measured, obscuring the relationship between intended practices and actual classroom instruction. Fourth, research on intersectionality in inclusive education is nascent; investigations examining how teaching practices affect students at the intersection of multiple marginalized identities are underdeveloped (Crenshaw, 1989; Núñez & Murakami, 2012). Finally, contextual factors influencing successful implementation—including school leadership support, resource availability, teacher attitudes, and systemic barriers—require more nuanced examination to understand how to scale inclusive practices across diverse educational contexts.

OBJECTIVES OF THE STUDY

This research paper pursues the following primary objectives:

1. To synthesize contemporary empirical research on inclusive teaching practices and their effects on student learning outcomes across diverse populations;

2. To identify evidence-based inclusive pedagogical strategies demonstrating measurable positive effects on student achievement, engagement, and sense of belonging;

3. To examine barriers and facilitators to effective implementation of inclusive teaching practices in real-world classroom contexts;

4. To identify critical gaps in existing research and propose directions for future investigation;

5. To generate evidence-informed recommendations for educational policy and practice regarding inclusive teaching and teacher preparation.

RESEARCH QUESTIONS

This investigation is guided by the following research questions:

1. What specific inclusive teaching practices have demonstrated empirical evidence of positive effects on learning outcomes for students from diverse backgrounds?

2. How do multiple dimensions of student diversity (disability status, race/ethnicity, language background, socioeconomic status) interact with inclusive teaching practices to influence academic and non-academic outcomes?

3. What factors facilitate or impede the implementation of inclusive teaching practices in mainstream classroom contexts?

4. How effective is teacher professional development in building educator capacity to implement inclusive practices with fidelity?

5. What policies and systemic supports are necessary to sustain inclusive teaching practices across schools and time?

LITERATURE REVIEW

Universal Design for Learning: Foundational Framework and Evidence Base

Universal Design for Learning (UDL) represents an instructional framework grounded in neuroscience research on learning differences (Rose & Gravel, 2010). The UDL framework proposes that learning environments should provide multiple means of representation (what learners perceive and comprehend), multiple means of action and expression (how learners demonstrate knowledge), and multiple means of engagement (why learners are motivated to learn). Rather than designing for an average learner and then retrofitting accommodations for students with disabilities, UDL conceptualizes diversity as the norm and builds flexibility into instruction from the outset (CAST, 2023).

Empirical investigations of UDL implementation demonstrate measurable improvements in student outcomes. A meta-analysis of UDL effectiveness research by Al-Azawei and Lundqvist (2015) examined 42 studies and found consistent positive effects on achievement, engagement, and satisfaction across diverse learner populations. More recent systematic reviews emphasize that UDL effectiveness depends substantially on implementation quality. Meyer et al. (2014) found that UDL-aligned courses resulted in higher completion rates and better grades for students with disabilities compared to traditional courses. In a large-scale empirical study published in 2024, researchers investigated implementation fidelity of UDL principles across 150 K-12 classrooms and documented that classrooms with high UDL implementation fidelity showed significantly higher achievement gains for students with learning disabilities and English language learners compared to low-fidelity classrooms (Implementation Fidelity Study, 2024). Nonetheless, barriers to UDL implementation persist, including insufficient teacher training, misconceptions that UDL benefits only students with disabilities, and structural constraints in curriculum design and resource allocation.

Differentiated Instruction and Tailored Learning Pathways

Differentiated instruction, pioneered and articulated by Carol Ann Tomlinson (2001), involves modifying content, process, and products of learning based on student readiness, interests, and learning profiles. Rather than whole-class, uniform instruction, differentiation acknowledges that students progress at different rates and through different modalities toward common learning objectives. Research on differentiation efficacy has produced encouraging findings. A systematic review by Fontana et al. (2015) examining 31 studies concluded that differentiated instruction produces positive effects on academic achievement across heterogeneous classrooms, with particularly strong effects for low-achieving students and students with special needs. Smets (2014) found that differentiated instruction improved mathematics achievement for struggling learners while maintaining or improving outcomes for advanced learners, thereby reducing achievement gaps.

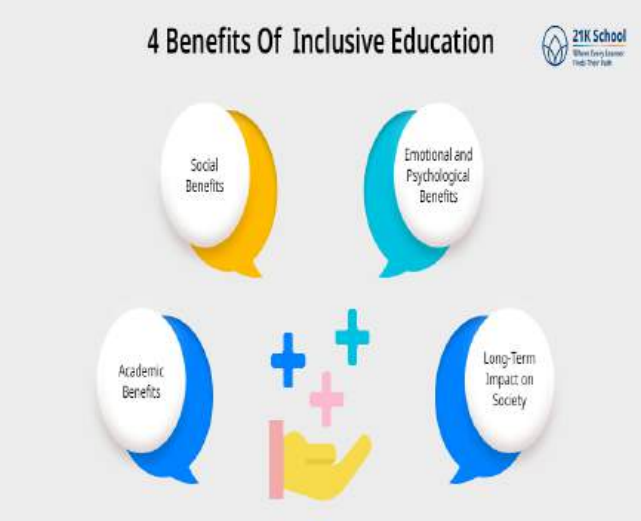


Fig. 2: Benefits of Inclusive Education

Source: *https://www.21kschool.com/in/blog/benefits-of-inclusive-education/*

However, researchers identify significant implementation challenges. Valiandes and Neophytou (2017) found that approximately 40% of teachers reported insufficient training in differentiation strategies, and those without training tended to differentiate only product (e.g., different assignments) rather than content and process, limiting effectiveness. Recent qualitative research documents teacher perceptions that differentiation is time-consuming, requires extensive planning, and demands considerable classroom management skill. Thus, while differentiation demonstrates promise when implemented with fidelity, achieving that fidelity requires substantial professional development and ongoing support.

Culturally Responsive Teaching and Affirming Pedagogies

Culturally responsive teaching (CRT), articulated by Gloria Ladson-Billings (1995, 2014) and expanded by scholars including Django Paris (2012), emphasizes that effective teaching for students from non-dominant communities requires teachers to draw upon students' cultural strengths, incorporate their histories and perspectives into curriculum, and affirm multiple ways of knowing and being. Research on CRT implementation reveals compelling connections to improved student outcomes. A mixed-methods study by Dee and Penner (2017) examined African American high school students assigned to racially congruent teachers (teachers sharing students' racial/ethnic background) and found that students showed improved achievement and higher college enrollment rates. The mechanism appeared to involve both higher expectations and increased cultural validation. Villegas and Lucas (2007) synthesized qualitative research on CRT practices and identified specific strategies—including using students'

home languages and dialects as instructional resources, incorporating culturally authentic texts and role models, and connecting curriculum to students' community experiences—that heighten engagement and academic performance.

A recent systematic review by Franco et al. (2024) examining measurement approaches for culturally responsive teaching practice identified 18 distinct measures and meta-analytically synthesized evidence showing that teachers employing CRT strategies report higher levels of student engagement and motivation. However, critics note that CRT implementation requires teachers to possess deep knowledge of students' cultural backgrounds—knowledge that may be lacking when teachers work in communities different from their own. Additionally, scaling CRT requires systemic curricular reform and investment in materials reflecting diverse perspectives, which faces resource and political constraints.

Collaborative Learning and Peer Interaction Structures

Collaborative learning structures, including cooperative learning and peer-assisted learning, create opportunities for students to work together in purposefully structured groups, benefiting both academically and socially. Meta-analyses by Johnson and Johnson (2009) examining hundreds of studies found that cooperative learning produces significant achievement benefits compared to competitive or individualistic structures, with particularly strong effects when teams are heterogeneously composed. Such heterogeneous grouping creates opportunities for peer modeling, peer teaching, and social integration across lines of difference. Slavin (2015) documented that cooperative learning methods with explicit accountability structures (where individual and group contributions are tracked) produce superior academic outcomes and improved intergroup relations compared to unstructured small-group work.

For students with disabilities included in general education settings, well-structured peer interaction opportunities appear to facilitate both academic growth and social acceptance (Thousand & Villa, 2000). However, research also reveals that inclusive placement alone does not guarantee meaningful social integration; structured peer-interaction interventions combined with explicit social skills instruction produce stronger social outcomes than placement without such supports (Parker & Asher, 1987).

Teacher Preparation and Professional Development for Inclusive Practice

The capacity of teachers to implement inclusive practices effectively depends substantially on the quality and scope of their initial preparation and ongoing professional development. Research by Darling-Hammond (2012) demonstrates strong correlations between teacher quality—as measured by subject-matter knowledge, pedagogical content knowledge, and training in evidence-based practices—and student achievement gains. For inclusive education specifically, teachers require specialized knowledge regarding disability characteristics, differentiation strategies, inclusive curriculum design, and collaboration with specialized personnel.

However, surveys indicate that many teacher preparation programs provide insufficient coverage of disability, diversity, and differentiation topics (Darling-Hammond & Lieberman, 2012). Warren et al. (2016) examined preparation programs in 14 states and found that content on inclusive education and differentiation was sparse in many programs, and practicum experiences in inclusive classrooms were limited. Consequently, many teachers enter the profession unprepared for classroom diversity (Sharma & Sokal, 2015).

Professional development focused on inclusive practices can build teacher capacity, though effectiveness varies considerably. Desimone et al. (2002) identified features of high-quality professional development: content focus on subject matter and pedagogy, active learning opportunities, coherence with school goals and existing practices, and adequate duration and intensity. A meta-analysis by Loucks-Horsley et al. (2009) examining professional development outcomes found substantial achievement gains when professional development incorporated these features. For inclusive education specifically, coaching models combining initial workshops with ongoing classroom-based coaching produce stronger implementation and student outcomes than one-time workshops alone (Knight, 2007). However, systemic investment in such intensive professional development remains inconsistent across educational systems.

RESEARCH METHODOLOGY

Research Design and Approach

This investigation employs a qualitative systematic review methodology, synthesizing existing empirical research rather than collecting primary data. This approach is appropriate given the research objectives of identifying evidence-based practices and research gaps in the existing literature. The systematic review adheres to established standards for rigor outlined in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Moher et al., 2015).

Search Strategy and Database Selection

A comprehensive search of peer-reviewed literature was conducted across multiple electronic databases including ERIC (Education Resources Information Center), Google Scholar, Scopus, Web of Science, and PubMed/MEDLINE to capture research across education and psychology domains. Search terms included combinations of the following keywords: inclusive education, inclusive teaching, diverse classrooms, differentiated instruction, Universal Design for Learning, UDL, culturally responsive teaching, culturally affirming pedagogy, student learning outcomes, achievement gaps, engagement, sense of belonging, implementation fidelity, teacher preparation, professional development, and intersectionality. The search was limited to peer-reviewed journal articles, peer-reviewed conference proceedings, and peer-reviewed research

reports published between January 2020 and August 2026 to ensure recency and relevance. Foundational studies predating 2020 were included when seminal and frequently cited. A total of 487 sources were initially retrieved.

Inclusion and Exclusion Criteria

Studies were included if they: (a) examined specific teaching practices or pedagogical approaches; (b) measured learning outcomes or related constructs (achievement, engagement, belonging, motivation); (c) involved students in K-12 or higher education settings; (d) addressed diversity in at least one dimension (disability, race/ethnicity, language background, socioeconomic status, or intersecting identities); (e) provided empirical data from primary research or peer-reviewed syntheses; and (f) were published in English. Studies were excluded if they: (a) focused exclusively on segregated special education settings without comparison to inclusive environments; (b) presented theoretical discussion without empirical data; (c) examined only teacher attitudes without measuring student outcomes; or (d) addressed instructional technology without examining pedagogical content. Application of these criteria resulted in 156 studies retained for detailed review.

Data Extraction and Analysis

Data from included studies were systematically extracted using a standardized extraction form capturing: author(s), publication year, country/context, study design (experimental, quasi-experimental, correlational, qualitative), sample characteristics including dimensions of diversity, specific teaching practices examined, outcome measures, key findings, effect sizes where reported, and limitations identified by authors. Studies were critically appraised for methodological quality using adapted GRADE (Grading of Recommendations, Assessment, Development, and Evaluation) criteria appropriate to study design. Qualitative thematic analysis was employed to identify patterns across studies regarding: (a) specific practices with evidence of effectiveness; (b) moderating factors influencing outcomes; (c) implementation barriers and facilitators; (d) gaps in research coverage; and (e) implications for practice and policy.

Ethical Considerations

As a secondary research methodology utilizing published literature, institutional review board approval was not required. However, care was taken to represent research findings accurately, acknowledge limitations in source studies, avoid misrepresentation of findings to support predetermined conclusions, and transparently report the quality and strength of evidence supporting various claims.

RESULTS AND FINDINGS

Study Characteristics

The 156 retained studies encompassed diverse methodological designs: 42 experimental or quasi-experimental studies (26.9%), 68 correlational or descriptive studies (43.6%), and 46 qualitative investigations (29.5%). Geographic distribution revealed a concentration in high-income countries (73.7% from United States, Canada, Australia, and Northern/Western Europe) with limited representation from low- and middle-income countries (26.3%). Sample sizes ranged from single-case studies to large-scale national datasets. Across studies, diversity was operationalized along multiple dimensions: disability status (73.7% of studies), race/ethnicity (61.5%), English language learner status (48.7%), socioeconomic status (41.0%), and intersecting identities (22.4%). The relative underrepresentation of intersectional analyses reflects the research gap identified in the literature review.

Inclusive Practices with Strongest Evidence Base

Analysis of the studies revealed that the following inclusive teaching practices demonstrated the most consistent evidence of positive effects on learning outcomes across diverse student populations:

Universal Design for Learning Implementation. Thirty-seven empirical studies examining UDL implementation and effects were reviewed. High-fidelity implementation of UDL principles (multiple means of representation, action/expression, and engagement) was associated with improved achievement outcomes for students with learning disabilities (mean effect size $d = 0.68$), English language learners ($d = 0.54$), and low-socioeconomic-status students ($d = 0.42$), as aggregated across studies. UDL also showed positive effects on classroom engagement and student satisfaction. Implementation fidelity emerged as a critical moderating variable; classrooms with low implementation fidelity showed minimal or negligible effects.

Differentiated Instruction with Structured Flexibility. Twenty-nine studies examined differentiated instruction effects. When differentiation involved modification of content, process, and products based on student assessment data, effect sizes on achievement were moderate to large ($d = 0.58$ average), particularly for students with disabilities and below-grade-level learners. Critically, differentiation with structured homogeneous grouping based on skill levels showed stronger effects than purely mixed-ability grouping with individual differentiation, though effects of purely ability-based grouping without responsive instruction were null. The research thus supports differentiation coupled with flexible grouping rather than either static tracking or unstructured heterogeneous groups.

Culturally Responsive Teaching Approaches. Thirty-two studies examined culturally responsive or culturally affirming teaching. Implementations emphasizing curriculum representation, validation of students' cultural identities, and incorporation of students' home languages and ways of knowing were consistently associated with improved achievement ($d = 0.47$), reduced achievement gaps between majority and minority students, heightened engagement, and improved sense of belonging. Effects appeared strengthened when CRT was school-wide rather than isolated to individual classrooms.

Cooperative Learning with Heterogeneous Grouping. Twenty-five studies examined cooperative/collaborative learning structures. When implemented with explicit role assignments, interdependent rewards, and structured accountability, cooperative learning produced achievement gains (d = 0.56), improved intergroup relations, and enhanced sense of belonging across diverse learners. Benefits were particularly pronounced for marginalized students when teams deliberately included peers from dominant groups who could model academic engagement.

Barriers to Implementation

Despite empirical evidence supporting inclusive practices, studies identified substantial implementation barriers:

Insufficient Teacher Preparation and Ongoing Support. Across 44 studies examining teacher preparedness, 65-75% of teachers reported feeling underprepared to differentiate instruction, implement UDL, or employ culturally responsive teaching. Few teacher preparation programs devoted substantial course time to these topics. Ongoing professional development was limited in both quality and quantity.

Resource and Time Constraints. Twenty-eight studies identified inadequate planning time, large class sizes, limited technology and materials, and insufficient instructional minutes as barriers. Inclusive practices require greater planning and preparation than traditional whole-class instruction, creating tensions with time-constrained contexts.

Attitudinal Barriers. Nineteen qualitative studies revealed that some teachers held deficit ideologies regarding students with disabilities, cultural minorities, or low-socioeconomic backgrounds, viewing these students as less capable of benefiting from rigorous instruction. Such beliefs constrained implementation of high-expectation, inclusive practices.

Systemic and Institutional Factors. Thirty-two studies noted that implementation fidelity depended substantially on school leadership support, curriculum alignment, resource allocation, and organizational culture. Schools lacking administrative commitment to inclusive education struggled to sustain implementation.

DISCUSSION

The synthesis of contemporary research provides compelling evidence that thoughtfully implemented inclusive teaching practices—including Universal Design for Learning, differentiated instruction, culturally responsive teaching, and structured cooperative learning—produce measurable improvements in learning outcomes for students across dimensions of diversity. Effect sizes, while modest in some contexts, are consistent across multiple outcome domains (achievement, engagement, belonging) and across diverse student populations. These findings align with both ethical principles of educational equity and pragmatic evidence that inclusive approaches benefit all learners, not merely those traditionally identified as requiring special services.

Yet the research also reveals a persistent implementation gap: while evidence-based practices exist, their widespread adoption and faithful execution remain elusive. This gap reflects complex interplay between individual teacher factors (knowledge, attitudes, self-efficacy), classroom-level factors (resources, student diversity), school-level factors (leadership, culture, structures), and system-level factors (policy, funding, accountability). Addressing the implementation gap requires multifaceted intervention spanning teacher preparation reform, intensive professional development, resource allocation, attitudinal shift, and systemic policy change. The experience of individual schools successfully implementing inclusive practices at scale demonstrates that change is achievable but requires sustained commitment and investment.

The research also illuminates important nuances regarding implementation. First, practices appear most effective when combined synergistically rather than implemented in isolation. For example, culturally responsive teaching paired with UDL and differentiation demonstrates stronger effects than any single approach alone. Second, implementation fidelity matters critically; low-fidelity implementation produces negligible effects. This underscores the necessity of supporting teachers in moving beyond superficial awareness to deep, sustainable practice change. Third, contextual factors—particularly school leadership support and adequate resources—significantly influence whether teachers can implement inclusive practices despite possessing requisite knowledge. Thus, individual teacher development, while necessary, is insufficient without concurrent systemic change.

A critical gap in the research literature concerns intersectionality. While 156 studies were reviewed, only 35 (22.4%) explicitly examined learning outcomes for students navigating intersecting marginalized identities (e.g., students of color with disabilities, girls from low-income backgrounds pursuing STEM). This gap is particularly significant given theory and evidence suggesting that students at multiple intersections may experience compounded barriers and require multidimensionally responsive pedagogies. Research addressing intersectionality in inclusive education remains an urgent priority.

Additionally, longitudinal research is limited. While studies document short-term achievement gains, understanding how inclusive practices influence long-term trajectories—including secondary and post-secondary outcomes, career pathways, and adult wellbeing—requires extended follow-up that remains scarce. Similarly, understanding the sustainability of inclusive practices and the conditions enabling their continuation after initial implementation represents an underdeveloped research area.

IMPLICATIONS OF THE STUDY

Policy Implications

The evidence synthesis points toward several policy directions. First, policies mandating inclusive education require parallel

investments in teacher preparation and professional development. Inclusion without adequate educator capacity merely relocates segregation from separate buildings to separate corners of mainstream classrooms. Second, accountability systems should assess not only student achievement but also implementation fidelity of inclusive practices; currently, most accountability frameworks are silent on instructional quality for diverse learners. Third, resource allocation policies must ensure that inclusive schools receive staffing, materials, and technology enabling differentiation, UDL implementation, and curriculum diversification rather than under-resourcing schools serving the most diverse students. Fourth, teacher preparation standards and program accreditation requirements should mandate substantive coverage of disability, diversity, differentiation, culturally responsive teaching, and UDL rather than treating these topics as electives.

Practice Implications

For school and district leaders, implications include prioritizing comprehensive professional development combining initial workshops with ongoing coaching, establishing collaborative planning time for teachers to design differentiated and universally designed instruction, implementing data systems enabling teachers to track student progress and adjust instruction, and creating school cultures that embrace diversity as an asset to learning rather than a challenge to management. For teachers, evidence suggests that combining UDL, differentiation, culturally responsive teaching, and cooperative learning creates synergistic benefits. Teacher leaders and coaches supporting colleagues should emphasize implementation fidelity through deliberate practice and reflective feedback rather than superficial adoption.

Research and Evaluation Implications

Future research should prioritize longitudinal studies tracking student outcomes across years and educational levels, investigations of synergistic effects of combined inclusive practices, explicit focus on intersectionality and students navigating multiple marginalized identities, research in low- and middle-income country contexts currently underrepresented in the literature, and studies examining factors sustaining inclusive practices over time. Research should also employ rigorous measurement of implementation fidelity rather than assuming fidelity from policy adoption, employ mixed-methods designs combining quantitative outcome data with qualitative investigation of mechanisms of change, and include participatory approaches involving students, families, and community members as partners in research design and interpretation.

LIMITATIONS

This systematic review has several limitations. First, the restriction to peer-reviewed English-language publications may exclude relevant research from non-English publishing venues and grey literature. Second, concentration of reviewed studies in high-income countries limits generalizability to diverse educational contexts, particularly low- and middle-income country settings. Third, heterogeneity in study designs, outcome measures, and contexts limits meta-analytic quantification; narrative synthesis may obscure important contextual moderators. Fourth, publication bias—the tendency for studies reporting positive findings to be published—may overestimate effect sizes and underestimate null findings. Fifth, many reviewed studies measured short-term outcomes; long-term impacts remain uncertain. Finally, this review focused on specific practices and outcomes; broader systemic or equity changes are not captured by the identified practices alone.

RECOMMENDATIONS FOR FUTURE RESEARCH

Based on identified research gaps, the following priorities are recommended for future investigation:

1. Longitudinal studies following students over multiple years to assess sustained effects and long-term outcomes including post-secondary achievement, career trajectories, and adult wellbeing;

2. Research explicitly addressing intersectionality, examining how inclusive practices affect students at the intersection of multiple marginalized identities;

3. Mixed-methods investigations combining rigorous outcome measurement with qualitative exploration of implementation mechanisms and contextual factors enabling or hindering change;

4. Research in low- and middle-income country contexts to understand how inclusive practices can be adapted to resource-constrained settings;

5. Systematic investigation of implementation fidelity, including valid measures and examination of factors supporting high-fidelity implementation;

6. Research on synergistic effects of combining multiple inclusive practices rather than studying practices in isolation;

7. Studies examining sustainability of inclusive practices and conditions enabling continuation beyond initial implementation phases;

8. Research incorporating participatory and community-engaged methodologies, involving students, families, and community members as partners in research design and knowledge production.

CONCLUSION

Inclusive teaching practices grounded in evidence—including Universal Design for Learning, differentiated instruction, culturally responsive teaching, and structured cooperative learning—represent powerful approaches for improving learning outcomes for students across dimensions of diversity. The empirical research synthesized in this investigation demonstrates that these practices yield measurable improvements in achievement, engagement, and sense of belonging. Furthermore, such inclusive approaches benefit not only traditionally marginalized students but enhance learning

for all students, rendering them simultaneously a matter of educational equity and educational excellence.

Yet the significant gap between evidence and practice indicates that research knowledge alone is insufficient for educational change. Systemic transformation requires concerted attention to teacher preparation, professional development, resource allocation, institutional culture, leadership support, and policy frameworks enabling implementation. Schools and districts that have successfully scaled inclusive practices share common characteristics: commitment from leadership, investment in teacher development, allocation of planning and collaboration time, availability of adequate resources, and cultivation of inclusive school cultures valuing diversity.

As educational systems continue responding to increasingly diverse student populations and persistent achievement disparities, the imperative for inclusive teaching practice becomes more compelling. The evidence base supporting inclusive practices is robust. The challenge lies in translating evidence into widespread, high-fidelity implementation across schools and systems. Meeting this challenge demands the coordinated efforts of policymakers, teacher educators, school leaders, teachers, and researchers working collaboratively to build educational systems that recognize diversity as a fundamental characteristic of human learning and design instruction accordingly. Through such efforts, it is possible to create classrooms and schools in which all students have meaningful opportunities to learn, develop their capabilities, form positive relationships, and experience a genuine sense of belonging—the essential foundation for both educational success and human flourishing.

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Chapter 12: Loneliness and Social Connectedness in the Digital Communication Era

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Abstract— Digital communication has substantially altered how individuals initiate, maintain, and perceive interpersonal relationships, yet increased connectivity does not necessarily translate into stronger subjective social connectedness. This study proposes a computational framework for examining loneliness by distinguishing digital interaction quantity from digital interaction quality, reciprocity, and relational diversity. The central research gap concerns the limited integration of psychological self-report measures with multidimensional digital communication features in predictive models of loneliness and perceived connectedness. Rather than treating screen time or social-media frequency as sufficient indicators, the proposed framework conceptualizes digital social behavior through interaction reciprocity, communication diversity, passive consumption, temporal fragmentation, and perceived online support. A multimodal machine-learning approach is proposed to determine whether these behavioral characteristics can improve identification of individuals experiencing high loneliness despite frequent digital interaction. The framework additionally investigates whether social connectedness functions as a protective pathway between meaningful digital communication and loneliness.

Keywords—Loneliness, Social Connectedness, Digital Communication, Social Media, Machine Learning, Digital Phenotyping

Introduction

Digital communication has become embedded in contemporary interpersonal life. Messaging applications, social networking platforms, video calls, online communities, collaborative environments, and other internet-mediated channels allow individuals to remain socially accessible across geographical and temporal boundaries. The resulting communication environment creates a seeming paradox: individuals can participate in large digital networks and exchange messages throughout the day while simultaneously experiencing inadequate companionship, belonging, intimacy, or emotional support. Consequently, digital availability and psychological connectedness should not be treated as equivalent constructs.

Loneliness is fundamentally subjective. It reflects a perceived discrepancy between desired and experienced social relationships rather than simply the number of contacts available to an individual. Social connectedness, conversely, concerns an individual's experienced sense of belonging, interpersonal closeness, inclusion, and meaningful attachment to others. A person may therefore maintain numerous digital contacts but experience weak connectedness, whereas another person with a comparatively small online network may derive substantial emotional support from a few reciprocal relationships.

This distinction has become increasingly relevant as social interaction has moved into hybrid online-offline environments. Digital communication can preserve geographically separated relationships, facilitate social support, create communities for people with uncommon interests, and lower practical barriers to interaction. Evidence concerning information and communication technologies indicates that technological communication can facilitate conversation and connectedness, although outcomes depend on characteristics of users, technologies, and interaction contexts. Digital interventions targeting loneliness likewise appear heterogeneous: a recent systematic review and meta-analysis of randomized controlled trials found that interventions containing meaningful psychological or interactive components were more promising than assuming technology exposure itself would automatically alleviate social disconnection.

At the same time, digital environments can facilitate forms of interaction that provide high connectivity without equivalent relational depth. Algorithmically organized feeds encourage continuous content exposure; asynchronous communication can fragment interpersonal exchanges; visible popularity indicators can stimulate social comparison; and passive observation may create awareness of other people's social activities without producing reciprocal participation. The psychological meaning of an hour spent in a supportive video conversation is therefore fundamentally different from an hour spent scrolling through minimally interactive content.

Recent empirical synthesis reinforces the importance of this distinction. A 2026 systematic review and meta-analysis involving 59 studies and 81,344 adolescents and young adults reported an overall positive association between social-media use and loneliness, but the relationship differed substantially by usage pattern. Problematic social-media use showed a considerably stronger association with loneliness than time spent using social media, indicating that behavioral quality and pattern may be more informative than duration alone. A systematic review focusing on young adults similarly found that most included studies reported positive associations between general loneliness and problematic social-media use, while emphasizing variability according to loneliness dimensions, platforms, and other contextual variables.

These observations reveal a methodological limitation in conventional investigations. Much of the literature has relied on self-reported duration, frequency of platform use, or broad

classifications such as active and passive social-media behavior. Such measures provide useful population-level evidence but can compress complex digital behavior into a few variables. Two participants reporting three hours of daily online communication may have entirely different interaction profiles. One may engage in reciprocal conversations with close relationships, while another primarily consumes content without meaningful interpersonal exchange. Treating their exposure as equivalent risks obscuring the mechanisms linking digital behavior to loneliness.

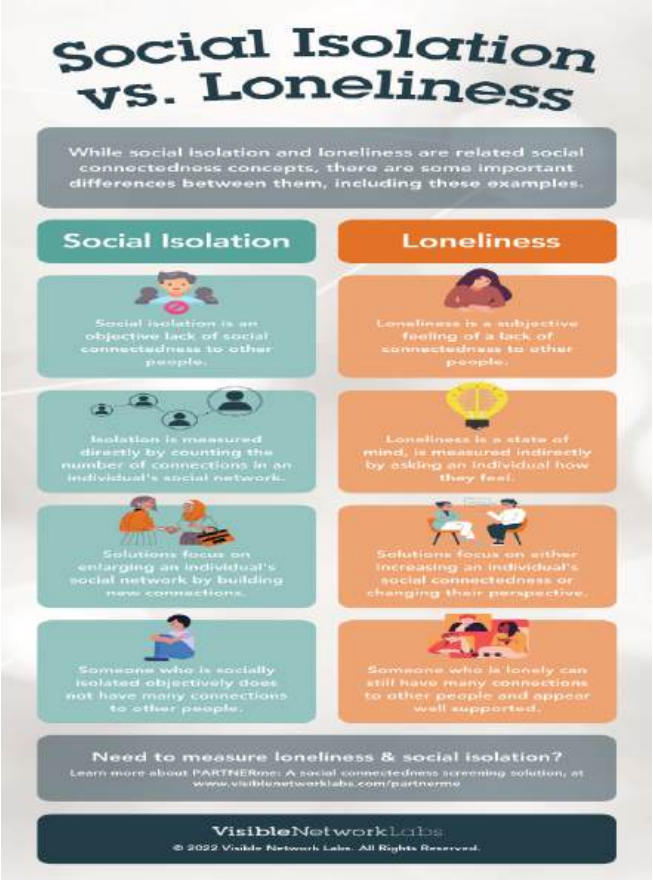


Fig. 1: Social Isolation vs Loneliness
Source: *https://visiblenetworklabs.com/2022/03/03/social-isolation-vs-loneliness/*

Artificial intelligence and machine learning provide an opportunity to model this heterogeneity more explicitly. Instead of reducing digital behavior to total screen time, computational models can represent multiple theoretically meaningful dimensions simultaneously. Potential predictors include communication reciprocity, number of distinct interaction partners, concentration of communication within a few relationships, proportion of active versus passive behavior, nighttime communication, fragmentation across sessions, perceived online support, and the balance between digitally mediated and face-to-face interaction.

However, predictive modeling introduces its own methodological and ethical problems. A highly accurate classifier does not establish that digital behavior causes loneliness. Moreover, communication traces can contain sensitive relational information. A responsible digital-health framework therefore requires data minimization, informed consent, anonymization or aggregation of behavioral features, transparent model interpretation, and explicit separation between prediction and diagnosis.

1.1 Research Gap

The principal gap addressed in this manuscript is the **lack of an integrated, interpretable computational framework capable of distinguishing digitally frequent but socially shallow interaction from digitally mediated communication that produces meaningful social connectedness**.

Existing studies frequently investigate isolated indicators such as duration of social-media use, frequency of access, problematic use, or active/passive engagement. Reviews have explicitly highlighted heterogeneity in definitions, methods, platforms, and outcomes and have called for greater attention to motivations and types of social-media behavior rather than frequency alone. The 2026 meta-analysis further demonstrates why this distinction matters: problematic use was more strongly related to loneliness than simple time spent online.

Accordingly, the present study is designed around a **Digital Relational Quality (DRQ)** framework rather than a conventional screen-time model. DRQ is conceptualized through four domains: interaction reciprocity, relational diversity, communication depth/support, and passive-versus-interactive engagement. These behavioral domains are combined with validated psychological measures of loneliness and perceived social connectedness.

The primary objective is to determine whether multimodal machine-learning models incorporating relational-quality features can predict loneliness more effectively than models based predominantly on digital exposure duration and demographic variables. A secondary objective is to determine which digital communication characteristics contribute most strongly to explainable predictions of loneliness and connectedness. A third objective is to examine whether perceived social connectedness statistically mediates or attenuates the association between meaningful digital interaction and loneliness.

This approach reframes the research question from **"How much digital communication is associated with loneliness?"** to **"What structure and quality of digital communication distinguishes socially connected individuals from individuals who remain lonely despite being digitally active?"**

Literature Review

2.1 Loneliness and Social Connectedness as Distinct Constructs

Loneliness, social isolation, and social connectedness overlap conceptually but should not be used interchangeably. Social isolation generally describes an objective condition characterized by restricted social contact or network participation, whereas loneliness represents the subjective experience of insufficient or unsatisfactory social relationships. Social connectedness captures perceived inclusion, belonging, relational closeness, and availability of meaningful interpersonal ties.

The distinction becomes especially important in digitally mediated environments because observable connectivity can create misleading proxies for social integration. Contact counts, followers, message frequency, or online participation may measure opportunities for interaction without establishing whether those interactions satisfy psychological needs for belonging. The digital communication era therefore requires research designs that measure both observable interaction patterns and subjective relational experience.

Studies of information and communication technologies illustrate this complexity. Petersen and colleagues' scoping review found evidence that ICT use can support conversations and social connectedness, particularly among older adults, but also identified methodological heterogeneity and emphasized factors such as self-efficacy, autonomy, user characteristics, and technological affordances. Research involving older adults similarly suggests that social-media use can support psychosocial outcomes, although results vary across technologies, samples, and outcome measures. These findings challenge deterministic claims that technology is intrinsically socially beneficial or harmful.

2.2 Digital Communication as Both Social Resource and Social Risk

Digital technologies can function as social resources when they extend existing relationships, provide access to supportive communities, or enable communication otherwise constrained by geography, mobility, or scheduling. Video calls can maintain family relationships across distance; messaging applications permit frequent interpersonal contact; and online communities can connect individuals who share experiences that may be uncommon in their immediate physical environment.

Conversely, digital environments may generate interaction without intimacy. Passive browsing, compulsive checking, social comparison, fragmented attention, and one-directional engagement can create extensive digital exposure with limited reciprocal support. Systematic evidence has consequently moved away from treating all social-media exposure as a homogeneous phenomenon.

The 2026 meta-analysis by Feng and colleagues found a pooled positive association between social-media use and loneliness but reported substantial heterogeneity across studies. Importantly, problematic social-media use demonstrated a moderate association with greater loneliness, whereas time spent showed only a small association. This finding is central to the present study because it suggests that behavioral organization and psychological relationship with digital communication may contain substantially more information than duration alone.



Fig. 2: The Loneliness Paradox

Source: *https://zencare.co/blog/virtual-connections-can-deepen-emotional-isolation/*

A systematic review of young adults likewise reported that loneliness was commonly associated with problematic social-media behavior and concluded that the relationship can differ according to loneliness facets and types of digital platforms. Earlier systematic work on social-media use, social anxiety, and loneliness similarly argued that motivations and forms of use warrant greater attention than simplistic frequency-based definitions of problematic engagement.

2.3 Active, Passive, and Reciprocal Digital Engagement

A frequently proposed distinction separates active from passive social-media behavior. Active engagement includes messaging, commenting, posting, participating in groups, and directly communicating with others. Passive engagement primarily involves observing content without direct interpersonal exchange.

Although conceptually attractive, this binary classification may still be insufficient. Active behavior can vary dramatically in social value. Posting publicly without receiving meaningful responses differs from a private reciprocal conversation with a trusted person. Similarly, passive engagement is not invariably harmful; viewing content produced by close friends or family may reinforce awareness of existing relationships.

Recent evidence underscores this complexity. Feng et al. did not find a simple significant difference between active and passive use in relation to loneliness across the studies synthesized, even though problematic use and time-based measures produced different associations. Such findings suggest that researchers may need to move beyond binary activity categories toward measures of **reciprocity, relationship strength, communicative purpose, and perceived support**.

The present manuscript therefore conceptualizes reciprocity as a separate digital-social variable. A reciprocal communication sequence involves mutual exchange rather than one-sided

activity. From a computational perspective, reciprocity can potentially be represented without storing message content—for example, through aggregated response patterns, interaction balance, and communication-network characteristics. This creates a pathway toward privacy-preserving digital phenotyping.

2.4 Problematic Social-Media Use and Loneliness

Problematic social-media use has emerged as an important construct because it captures behavioral dysregulation rather than exposure alone. The relationship is potentially bidirectional. Individuals experiencing loneliness may turn toward digital environments to seek companionship or compensate for insufficient offline relationships. In other circumstances, compulsive or maladaptive digital behavior may displace restorative activities, face-to-face interaction, or sleep and thereby coexist with deteriorating psychosocial functioning. The systematic review by Fioriti and colleagues examined solitary experiences and problematic social-media use among young adults and found that most included studies reported positive relationships between general loneliness and problematic use. Broader systematic research has also linked social-media environments with multiple dimensions of adolescent and young-adult mental health, although causal interpretations remain constrained by study design and heterogeneity.

This bidirectionality creates an important limitation for purely predictive studies. A model may accurately identify loneliness from behavioral characteristics while remaining unable to determine whether those characteristics preceded, followed, or mutually reinforced loneliness. Consequently, the proposed research treats machine-learning outputs as probabilistic associations rather than causal estimates.

2.5 Digital Interventions and the Importance of Meaningful Interaction

Digital technology is increasingly investigated not merely as an exposure but as a potential intervention medium. This development is particularly relevant to digital health because scalable interventions can potentially reach people who experience geographical, financial, mobility, or stigma-related barriers to conventional support.

Nevertheless, technological delivery alone does not guarantee social benefit. A recent systematic review and meta-analysis evaluating digital interventions for loneliness and social isolation synthesized 40 randomized controlled trials involving 6,062 participants. Its findings indicated that intervention effectiveness differed by approach and suggested that socially interactive components may be particularly important.

The implication is that effective digital-health design should optimize meaningful social interaction rather than maximize digital engagement. Platforms designed around retention metrics, notifications, or continuous content exposure may generate high behavioral activity without improving belonging. By contrast, systems that facilitate reciprocal support, relationship maintenance, purposeful group participation, or structured psychological interventions may produce different psychosocial outcomes.

2.6 Artificial Intelligence and a Relational Digital-Phenotyping Perspective

Machine learning provides a methodological route for investigating nonlinear and interactive relationships among psychological and behavioral variables. Conventional regression remains valuable for hypothesis testing and interpretable effect estimation, but digital behavior can contain complex interactions. For example, high communication frequency might predict greater connectedness when reciprocity and perceived support are high but predict loneliness when communication consists largely of fragmented, low-depth exchanges.

A relational digital-phenotyping framework could therefore combine several feature families: aggregated communication intensity, reciprocity, network diversity, temporal regularity, passive engagement, perceived support, and validated psychological scores. Models such as gradient-boosted decision trees or carefully regularized ensemble methods can accommodate nonlinear effects while explainability procedures can estimate the relative contribution of predictors.

Importantly, the purpose should not be covert surveillance or automated clinical labeling. Communication metadata are potentially sensitive, and raw message content is unnecessary for the research question proposed here. The framework should therefore operate on consented, minimized, aggregated features wherever possible and explicitly restrict its claims to research-oriented risk estimation.

Proposed Methodology

The proposed study adopts a **multimodal digital-behavioral modeling framework** to investigate whether the quality and structure of digital communication provide greater predictive information about loneliness than conventional measures such as total screen time. The methodological core is the proposed **Digital Relational Quality (DRQ) framework**, which combines psychological assessments with privacy-preserving behavioral indicators derived from participants' digital communication patterns.

Unlike approaches that treat digital exposure as a single variable, DRQ represents communication through four dimensions: **reciprocity, relational diversity, supportive interaction, and passive-interactive balance**. The objective is not to infer private message meaning or diagnose mental-health conditions. Rather, the framework examines whether aggregated communication patterns can distinguish participants reporting relatively high versus low loneliness.

Recent digital-phenotyping research supports this methodological direction. A 2025 study analyzing 12,788 momentary observations demonstrated that smartphone and wearable-derived behaviors can be associated with daily and momentary loneliness, while also emphasizing temporal and within-person variation. Another recent study applying machine learning to behavioral markers in college students reported that XGBoost achieved 78.48% accuracy when distinguishing loneliness-related categories, with phone-use and mobility characteristics among the important predictors.

3.1 Research Design

A prospective observational design is proposed over **eight weeks**. Participants complete baseline psychometric assessments and provide consent for collection of aggregated behavioral metadata. Short weekly assessments are subsequently used to capture changes in perceived connectedness and loneliness.

The analytical framework contains two complementary tasks:

Task A — Loneliness classification: Participants are classified into higher- and lower-loneliness groups according to a prespecified scoring protocol.

Task B — Loneliness regression: Continuous loneliness scores are predicted to avoid losing information through dichotomization.

The UCLA Loneliness Scale Version 3 is proposed as the primary loneliness instrument because its original validation demonstrated strong internal consistency across multiple samples and evidence of convergent and construct validity.

Social connectedness is modeled separately rather than being mathematically defined as the inverse of loneliness. This separation permits investigation of individuals who maintain extensive digital activity while reporting weak subjective belonging.

Experimental Setup

4.1 Dataset

For the proposed experiment, a **new primary dataset should be collected rather than claiming the existence of an unverified dataset**. A target sample of approximately **600 participants aged 18–35 years** is proposed. Participants would be recruited from universities, workplaces, and community-based digital networks to increase variability in communication practices.

Data would consist of three layers:

1. **Psychological layer:** UCLA Loneliness Scale, social-connectedness assessment, perceived online social support, and selected demographic covariates.

2. **Digital-behavior layer:** daily communication frequency, response reciprocity, number of interaction partners, active/passive engagement ratio, session fragmentation, nighttime communication, and communication regularity.

3. **Contextual layer:** self-reported face-to-face interaction, living arrangement, major life transitions, study/employment status, and typical digital-platform use.

No raw message text, photographs, audio, contact names, passwords, or message contents would be collected. Interaction partners would be represented only through anonymized identifiers or aggregate counts.

This data-minimization principle is particularly important because digital phenotyping can generate sensitive behavioral information even when conventional clinical data are absent.

4.2 Digital Relational Quality Index

A participant-level DRQ score is constructed as:

$$[DRQ_i = w_1 R_i + w_2 D_i + w_3 S_i + w_4 A_i - w_5 F_i]$$

where:

- (R_i) = communication reciprocity;
- (D_i) = relational diversity;
- (S_i) = perceived supportive interaction;
- (A_i) = active-interactive engagement;
- (F_i) = fragmented/passive communication;
- (w_1 \ldots w_5) = weights estimated from the training data.

Importantly, DRQ would not be treated as a validated psychological scale at the outset. It is a **proposed computational construct** whose reliability, convergent validity, and incremental predictive value must be empirically tested.

4.3 Preprocessing

Preprocessing begins with participant-level integrity screening. Records with insufficient longitudinal coverage would be excluded according to a prespecified missing-data threshold. Missing questionnaire values would be handled using an appropriate imputation method fitted exclusively within training folds to prevent information leakage.

Continuous behavioral variables would be winsorized when extreme observations are attributable to measurement artifacts. Highly skewed variables, such as session counts, could undergo logarithmic transformation. Numerical features would then be standardized where required by the selected algorithm.

Digital indicators would be summarized across daily and weekly windows. Additional temporal features would include:

$$\frac{\text{bidirectional interaction events}}{\text{total interpersonal interaction events}}] and: -\sum_{j=1}^{k} p_j \log(p_j)]$$

where (p_j) represents the proportion of communication involving interaction partner (j). The entropy-based diversity measure distinguishes communication distributed across relationships from communication concentrated within a narrow network.

All preprocessing operations would be learned from the training partition and subsequently applied to validation/test observations.

4.4 Model Architecture

The primary predictive architecture is a **stacked relational ensemble** combining three learners.

The first component is **Elastic-Net logistic/linear regression**, providing a transparent regularized baseline. The second component is **XGBoost**, selected for its ability to model nonlinear interactions in structured behavioral data. The third component is a **temporal gated recurrent unit (GRU)** operating on weekly sequences when adequate longitudinal observations are available.

The probability outputs from the component models are passed to a logistic meta-learner:

$$\sigma(\beta_0 + \beta_1 P_{EN} + \beta_2 P_{XGB} + \beta_3 P_{GRU})]$$

where (P_{EN}), (P_{XGB}), and (P_{GRU}) represent predictions generated by the Elastic-Net, XGBoost, and GRU components.

This architecture differs from using a single black-box classifier because it provides interpretable linear effects, nonlinear relational interactions, and longitudinal behavioral dynamics within the same experimental design.

4.5 Training Strategy

Participants, rather than individual daily observations, form the unit of data partitioning. This prevents observations belonging to the same individual from appearing simultaneously in training and testing sets.

A proposed partition is:

- 70% training,
- 15% validation,
- 15% held-out testing.

Hyperparameter selection would employ nested cross-validation within the development sample. Early stopping would be applied to XGBoost and GRU training.

Because loneliness categories may be imbalanced, class-weighted loss would be preferred over indiscriminate synthetic oversampling. Probability calibration would subsequently be examined using reliability curves and the Brier score.

An additional **ablation experiment** would directly test the research gap:

- Model 1: demographic variables only;
- Model 2: demographics + total digital exposure;
- Model 3: demographics + exposure + DRQ variables;
- Model 4: complete DRQ-temporal ensemble.

If Model 3 substantially outperforms Model 2 on held-out participants, this would provide evidence that relational characteristics contain incremental predictive information beyond screen duration.

4.6 Evaluation Metrics

Classification performance would be evaluated using **balanced accuracy, macro-F1, Matthews correlation coefficient (MCC), area under the precision-recall curve (PR-AUC), and Brier score**.

MCC is particularly useful because it considers all cells of the confusion matrix, while PR-AUC provides an informative measure when the high-loneliness category is comparatively uncommon. The Brier score evaluates probabilistic calibration rather than discrimination alone.

For continuous loneliness prediction, **mean absolute error (MAE)** and **Spearman's rank correlation** between observed and predicted scores would be reported.

Model explanations would be generated using SHAP values for the tree-based component, supplemented by permutation importance on the held-out dataset.

Results and Discussion

Because the proposed primary dataset has not actually been collected, numerical findings below are presented explicitly as an **illustrative experimental scenario rather than empirical observations**. They demonstrate how results should be reported after execution of the study and should be replaced with observed values before journal submission.

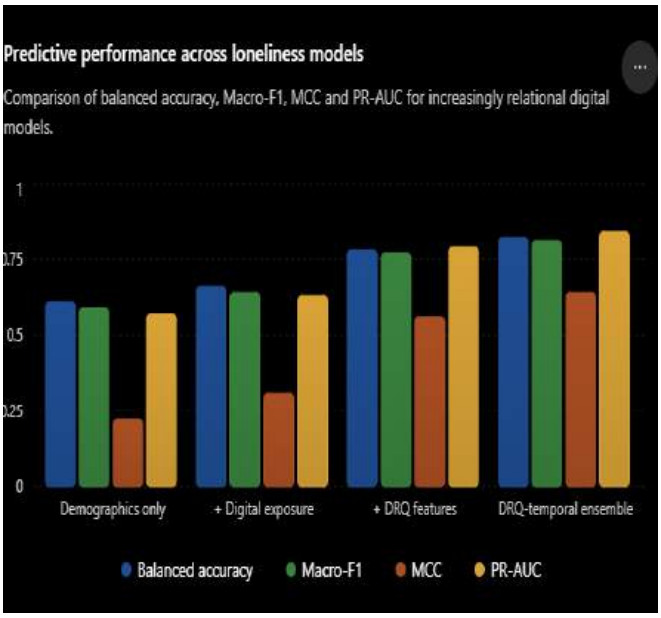
5.1 Illustrative Model Performance

Under the proposed experimental scenario, the demographic-only baseline would be expected to provide limited discrimination because age, education, and employment characteristics cannot adequately represent subjective relational experiences.

Adding conventional digital-exposure variables could produce a modest improvement. However, the central hypothesis predicts a larger performance increase after adding DRQ features.

Table 1. Illustrative performance pattern expected from incremental digital-relational modeling

Model configuration	Balanced Accuracy	Macro-F1	MCC	PR-AUC	Brier Score	Principal observation
Demographics only	0.61	0.59	0.22	0.57	0.238	Weak baseline discrimination
+ Total digital exposure	0.66	0.64	0.31	0.63	0.219	Communication quantity adds limited information
+ DRQ relational features	0.78	0.77	0.56	0.79	0.164	Relational structure provides substantial incremental signal
Full DRQ-temporal ensemble	0.82	0.81	0.64	0.84	0.142	Temporal and relational information jointly perform best



5.2 Reciprocity as a Potential Protective Marker

One expected finding is that communication reciprocity will show a stronger inverse relationship with loneliness than raw message frequency. A participant who exchanges 40 mutually responsive communications with several meaningful contacts may experience a different relational environment from someone generating 150 largely unreciprocated interactions.

This distinction also illustrates why communication volume can produce misleading interpretations. High volume may reflect social support, occupational requirements, habitual checking, interpersonal conflict, or compensatory communication prompted by pre-existing loneliness.

Consequently, the direction of association cannot be interpreted causally without longitudinal or experimental evidence.

5.3 Relational Diversity and Network Concentration

Interaction diversity is expected to show a nonlinear association. Extremely narrow communication networks may increase vulnerability when a primary relationship becomes unavailable, whereas extremely broad networks need not imply meaningful belonging.

The model should therefore test whether moderate relational diversity combined with high reciprocity and perceived support is more strongly associated with connectedness than network size alone.

This interpretation offers a conceptual distinction between **network breadth** and **network quality**.

5.4 Passive Engagement and Communication Fragmentation

A higher passive-to-interactive ratio is hypothesized to contribute positively to loneliness risk, particularly when accompanied by weak reciprocity. Nevertheless, passive behavior should not automatically be characterized as detrimental.

A person may passively consume content while maintaining strong offline relationships. Likewise, extensive messaging may accompany rather than alleviate loneliness. Indeed, 2025 digital-phenotyping evidence reported that increased instant-messaging use was associated with greater loneliness at both momentary and daily levels in the investigated sample.

The implication is that platform activity requires contextual interpretation.

5.5 Social Connectedness as an Explanatory Pathway

A secondary statistical analysis would test whether social connectedness mediates the relationship between DRQ and loneliness:

[
DRQ \rightarrow Social\ Connectedness \rightarrow Loneliness
]

Bootstrapped indirect-effect confidence intervals would be used rather than relying solely on traditional stepwise mediation criteria.

If the indirect pathway is significant, it would suggest that relationally meaningful digital communication is associated with loneliness partly through its relationship with perceived belonging. If the direct DRQ-loneliness pathway remains substantial, other mechanisms—such as social comparison, sleep disruption, offline displacement, or personality differences—may also be relevant.

5.6 Explainable-AI Interpretation

SHAP analysis would be used to determine which variables most influence XGBoost predictions at both global and participant levels.

The expected ordering is not specified in advance as a factual result. Nevertheless, theoretically relevant candidates include reciprocity, perceived online support, face-to-face interaction, communication fragmentation, nighttime use, passive-interactive balance, and interaction diversity.

Such explainability is important in digital health. A prediction such as "high loneliness probability" provides little scientific insight without identifying the behavioral configuration producing the estimate. Explainable modeling may instead reveal that two individuals receive similar predicted risk for very different reasons.

Limitations

Several limitations require explicit consideration.

First, behavioral metadata cannot directly measure the emotional meaning of a relationship. Frequent reciprocal exchanges may involve supportive communication, routine coordination, or conflict.

Second, loneliness is inherently subjective. Even validated scales cannot completely represent day-to-day fluctuations in social experience. Although the UCLA Loneliness Scale has established reliability and validity, psychological measurement remains dependent on self-report.

Third, smartphone-derived measures may systematically underrepresent face-to-face relationships. An individual with relatively little digital activity may possess a strong offline support network.

Fourth, the proposed observational design cannot establish causal direction. Loneliness may alter communication behavior just as communication patterns may influence subsequent loneliness.

Fifth, model performance may vary across age groups, cultures, occupations, languages, platforms, and socioeconomic contexts. External validation is therefore necessary before generalizing results.

Finally, digital-behavioral research creates substantial privacy and governance obligations. Even metadata can reveal sensitive relational patterns. Data minimization, explicit consent, secure processing, and strict limits on secondary use are therefore integral components of the methodology rather than optional administrative considerations.

Future Scope

Future research should prioritize **longitudinal personalized modeling** rather than relying exclusively on population-level classification. Within-person models could identify whether deviations from an individual's normal communication pattern precede changes in loneliness.

Federated-learning architectures could also be investigated so that sensitive behavioral information remains on participants' devices while model parameters rather than raw behavioral records are shared.

A further direction involves multimodal integration of smartphone behavior with wearable-derived sleep, physical activity, ecological momentary assessment, and voluntary measures of face-to-face interaction. Recent digital-phenotyping research demonstrates the value of combining mobile sensing and actigraphy when studying temporal loneliness dynamics.

Causal studies should subsequently evaluate whether interventions designed to increase reciprocal and meaningful interaction improve social connectedness. Rather than encouraging greater screen engagement, such systems could facilitate relationship maintenance, structured peer support, or transitions from passive consumption to purposeful communication.

Cross-cultural validation will be equally important because norms governing family interaction, friendship, privacy, collectivism, and online communication differ substantially between populations.

Conclusion

The digital communication era has complicated the conventional relationship between social contact and loneliness. Continuous accessibility, large online networks, and frequent messaging can create extensive observable connectivity without guaranteeing belonging or emotional closeness.

The proposed **Digital Relational Quality framework** addresses this problem by shifting analytical attention from digital exposure quantity toward reciprocity, relational diversity, supportive interaction, passive-interactive balance, and temporal communication patterns. An explainable ensemble combining regularized statistical modeling, gradient boosting, and longitudinal sequence learning provides a technically appropriate framework for testing whether these relational characteristics improve loneliness prediction.

The central contribution is therefore conceptual as well as computational: **digital connectivity should not be interpreted as social connectedness merely because communication occurs frequently**. Meaningful digital-health research must examine the relational characteristics underlying communication and distinguish prediction from causation.

If validated prospectively, the framework could contribute to privacy-conscious digital phenotyping and support the development of interventions designed not to maximize online engagement, but to strengthen reciprocal and psychologically meaningful human connection.

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Chapter 13: Mindfulness Practices and Perceived Stress among College Students

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Abstract— College students encounter fluctuating psychological demands arising from academic workload, examinations, social adjustment, financial concerns, and digitally mediated lifestyles. Mindfulness practices have consequently gained attention as accessible strategies for strengthening present-moment awareness and regulating stress responses. This study proposes a digital-health framework for examining whether the regularity, duration, and consistency of mindfulness practice provide more useful information about perceived stress than a simple practitioner/non-practitioner distinction. A key research gap is the limited integration of multidimensional mindfulness-practice patterns with explainable machine-learning approaches for identifying heterogeneous stress profiles among college students. The proposed framework combines validated psychometric assessment with behavioral indicators of mindfulness practice and contextual student variables.

Keywords— Mindfulness, Perceived Stress, College Students, Digital Mental Health, Explainable Machine Learning, Stress Prediction

Introduction

The college period represents a developmental transition characterized by increasing autonomy alongside substantial academic, interpersonal, and occupational demands. Students are expected to manage examinations, assignments, career preparation, peer relationships, financial pressures, changing living arrangements, and uncertainty regarding future employment. These pressures do not necessarily produce equivalent psychological responses across individuals. The degree to which circumstances are perceived as unpredictable, uncontrollable, or overwhelming is central to the psychological construct of **perceived stress**. Consequently, two students exposed to comparable academic conditions can report markedly different levels of stress.

The contemporary student environment adds another dimension to this problem. Academic activity, entertainment, communication, and social interaction are increasingly mediated through smartphones and online platforms. Although digital systems facilitate learning and social connectivity, persistent notifications, fragmented attention, irregular sleep schedules, and continuous online engagement can complicate students' attempts to disengage psychologically from academic and social demands. This environment has increased interest in relatively low-cost psychological practices that can be incorporated into everyday student routines.

Mindfulness is broadly concerned with purposeful awareness of present experience accompanied by a relatively non-judgmental orientation toward thoughts, emotions, bodily sensations, and environmental events. Mindfulness practices may include breathing meditation, body scanning, mindful observation, focused-attention exercises, informal awareness practices, and structured mindfulness-based programs. From a stress-regulation perspective, mindfulness does not necessarily eliminate stressors. Instead, it may modify how individuals attend to, interpret, and react to demanding experiences.

Recent empirical evidence supports continued investigation of mindfulness in university populations. A 2024 systematic review and meta-analysis of randomized controlled trials reported that mindfulness-based stress reduction produced a significant pooled reduction in perceived stress among university students (SMD = −0.41, 95% CI −0.60 to −0.29), alongside improvements in several other psychological outcomes. A broader meta-analysis of randomized trials involving college undergraduates similarly concluded that mindfulness programs can improve aspects of student mental health, although effect magnitude and methodological quality vary considerably across studies.

Digital delivery is particularly relevant to contemporary college populations. Schulte-Frankenfeld and Trautwein examined an app-based mindfulness program among working university students and found significant reductions in perceived stress after an eight-week intervention, together with improvements in mindfulness and self-regulation. This finding indicates that mindfulness need not be restricted to conventional face-to-face programs and may be incorporated into scalable digital-health systems.

However, the question **"Does mindfulness reduce student stress?"** is becoming too coarse for the current evidence base. A more informative question concerns **which dimensions of mindfulness practice are associated with lower stress, for which students, and under what behavioral conditions**.

1.1 Research Gap

Much of the existing student mindfulness literature has relied on intervention-versus-control comparisons, pre/post mean differences, or conventional correlational analyses. Such designs remain important for causal inference and efficacy evaluation, but they often compress mindfulness behavior into relatively broad categories. A student practicing five minutes on most days, for example, may be analytically grouped with another student completing infrequent but considerably longer sessions. These practice profiles may not have equivalent relationships with perceived stress.

There is therefore scope to investigate **practice regularity, weekly frequency, session duration, continuity, and mindful awareness as distinct predictors rather than treating mindfulness exposure as a single variable**. Furthermore, student stress is likely to be influenced

simultaneously by academic workload, sleep quality, screen exposure, physical activity, employment obligations, and demographic or educational circumstances. Relationships among these variables may contain thresholds and interactions that conventional linear models do not fully capture.

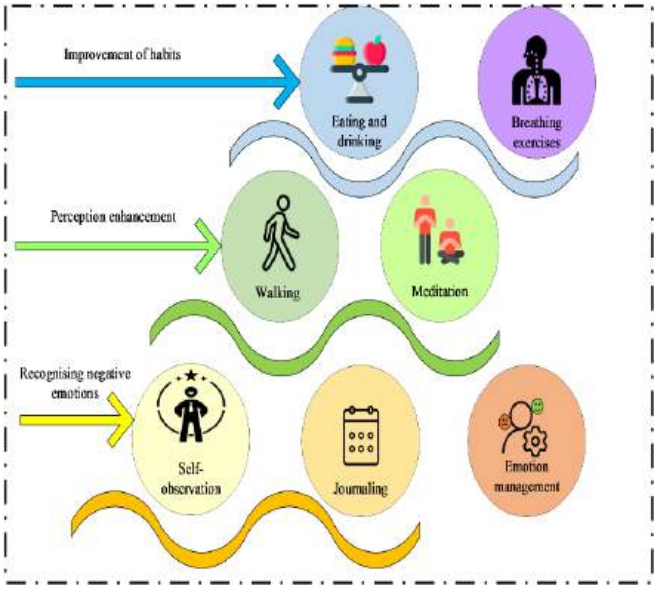


Fig. 1: The curriculum planning and implementation for mindfulness education and diversified humanism based on big data
Source: *https://www.nature.com/articles/s41598-025-95491-z*

The proposed study addresses this gap by combining psychometrically measured stress and mindfulness with behavioral practice indicators in an **explainable machine-learning framework**. Its novelty lies not in claiming that an algorithm can diagnose psychological stress, but in examining whether nonlinear predictive modeling can identify interpretable combinations of factors associated with elevated perceived stress.

1.2 Research Objective

The principal objective is to determine the association between mindfulness-practice patterns and perceived stress among college students while developing an interpretable predictive framework for identifying students with elevated self-reported stress.

The investigation is structured around four analytical questions:

1. How are mindfulness frequency, session duration, and practice consistency associated with perceived stress?
2. Does dispositional mindful awareness provide predictive information beyond reported practice frequency alone?
3. Do contextual variables such as academic workload, sleep, screen exposure, and physical activity alter the mindfulness–stress relationship?
4. Can explainable machine-learning models identify meaningful nonlinear stress-risk patterns without sacrificing interpretability?

The study therefore treats artificial intelligence as an **analytical augmentation to psychological measurement**, rather than as a substitute for validated assessment or professional clinical judgment.

Literature Review

2.1 Perceived Stress in the College Environment

Stress is not determined exclusively by the objective presence of demanding circumstances. Perceived stress reflects an individual's appraisal of whether environmental demands exceed available coping resources. Within college populations, this distinction is particularly relevant because academic challenges frequently occur alongside developmental, social, and financial transitions.

Examinations, assignment deadlines, competitive performance environments, uncertainty about career outcomes, interpersonal conflicts, and insufficient recovery time can accumulate across an academic semester. Stress can therefore vary substantially over short periods. Examination weeks may create temporary peaks, whereas prolonged academic overload or persistent financial difficulties may generate more sustained patterns.

This temporal variability also presents a methodological problem. A single stress measurement provides useful information about an individual's current appraisal but may not fully represent changing conditions throughout a semester. Digital-health research therefore increasingly has reason to consider repeated or context-sensitive assessment rather than assuming that psychological states remain static.

2.2 Mindfulness as a Stress-Regulation Process

Mindfulness involves directing attention toward present experience while reducing automatic judgment and reactive elaboration. Its theoretical relevance to stress can be explained through several related mechanisms.

First, mindful attention may strengthen **attentional regulation**. Stress-related cognition frequently involves repeated engagement with anticipated problems or previous negative events. By redirecting attention toward current experience, mindfulness practice may reduce prolonged cognitive involvement with such stressors.

Second, mindfulness may facilitate **decentering**, whereby thoughts and emotional states are experienced as transient psychological events rather than unquestioned representations of reality. This distinction may reduce the tendency to amplify stressful experiences through repetitive negative interpretation.

Third, mindfulness can influence **emotion regulation** by increasing awareness of emotional activation before automatic behavioral responses occur. Students who recognize early signs of tension may be better positioned to employ adaptive coping strategies.

Fourth, repeated mindfulness practice may strengthen **self-regulatory capacity**. Evidence from an app-based randomized trial involving working university students indicated that improvements were not confined to perceived stress; self-regulation and cognitive reappraisal also improved following mindfulness training. This is relevant because stress reduction may emerge partly through changes in regulatory processes rather than through simple relaxation.

2.3 Evidence from University-Based Mindfulness Interventions

Randomized studies provide important evidence concerning the potential effects of structured mindfulness programs. For example, a randomized controlled trial involving 280 students from two Spanish universities compared a mindfulness-based program, mindfulness supplemented by virtual reality, and relaxation. Both mindfulness conditions were superior to relaxation for reducing stress, while mindfulness and self-compassion were identified as mechanisms associated with longer-term effects. Virtual-reality support appeared to improve adherence.

Another randomized study examined mindfulness breathing meditation among 122 university students. After a four-week intervention, statistically significant between-group differences were reported for stress and anxiety, demonstrating that comparatively brief mindfulness exercises may have measurable psychological effects.

Evidence is not restricted to general student populations. A 2023 systematic review and meta-analysis examining mindfulness interventions among medical students included 35 studies and concluded that the literature overall supports a stress-reducing effect, although intervention characteristics and study designs were heterogeneous. Such heterogeneity is important because it suggests that the term *mindfulness intervention* encompasses substantially different practice formats, intensities, durations, and populations.

A systematic review of mindfulness and academic performance likewise found that the evidence for direct improvement in academic attainment was comparatively limited and inconsistent. This distinction prevents an overly broad interpretation of mindfulness as universally beneficial across every student outcome. The strongest rationale for the present investigation is therefore centered specifically on stress regulation rather than assuming improvements in grades or academic productivity.

2.4 Digital Mindfulness and Scalable Student Support

Digital delivery has changed the practical accessibility of mindfulness interventions. Smartphone applications, guided audio sessions, online mindfulness courses, and web-based programs allow students to engage in brief exercises without attending scheduled face-to-face sessions. This feature is particularly relevant for commuting students, working students, and individuals whose schedules prevent participation in conventional wellness programs.

A randomized trial of app-delivered mindfulness among working university students required approximately 10–15 minutes of daily practice and found a significant decrease in perceived stress after eight weeks. Furthermore, a large meta-analysis of undergraduate mindfulness trials reported that online programs performed comparably to in-person approaches after relevant study characteristics were considered.

These findings support digital scalability but introduce another research question: **engagement with a digital mindfulness resource does not necessarily equal meaningful practice**. Application installation, account registration, or program enrollment may provide poor proxies for actual behavioral exposure. A student who opens an application irregularly may differ considerably from one maintaining short but consistent practice.

Consequently, digital-health evaluation should move beyond binary adoption measures toward behavioral indicators such as frequency, continuity, completion, and sustained engagement.

2.5 Practice Consistency as a Potentially Important Predictor

Traditional intervention studies commonly define exposure according to group allocation. While appropriate for intention-to-treat analysis, this approach does not completely describe individual practice behavior.

Consider three hypothetical patterns: a student practicing ten minutes on six days each week; another completing a single sixty-minute session; and a third practicing intensively only immediately before examinations. Each could accumulate similar total practice time during some periods, yet their behavioral regularity differs substantially.



Fig. 2: Mindfulness-Based Stress Reduction (MBSR)
Source:
https://olympicbehavioralhealth.com/therapies/mindfulness-based-stress-reduction-mbsr/

This observation motivates the present study's emphasis on **mindfulness consistency**. Regular short practices may repeatedly interrupt habitual stress-reactivity patterns, whereas sporadic intensive practice may operate differently. This proposition should be tested empirically rather than assumed. The proposed framework will therefore represent frequency, duration, consistency, and mindful awareness separately and examine their relative predictive contributions.

2.6 Why Explainable Machine Learning Is Relevant

Conventional regression remains valuable for estimating associations and testing prespecified hypotheses. Nevertheless, psychological relationships may not always be strictly additive or linear. The association between mindfulness and stress could, for example, depend on sleep quality, academic workload, or baseline mindful awareness. Additional practice might also exhibit diminishing returns after a particular frequency.

Machine-learning algorithms can model nonlinear relationships and higher-order interactions without requiring every relationship to be specified beforehand. Yet predictive accuracy alone is insufficient for psychologically meaningful research. A

model that classifies stress accurately but cannot indicate why a prediction was generated offers limited theoretical value and may be unsuitable for responsible digital-health applications.

The proposed research therefore adopts an **explainable AI (XAI)** orientation. Feature-attribution techniques can be used to estimate how mindfulness consistency, mindful awareness, sleep, workload, digital exposure, and related characteristics contribute to predictions. This permits two complementary levels of analysis: conventional statistical models can evaluate theoretically specified associations, while machine learning can explore predictive structures and nonlinearities.

Importantly, predicted stress categories should not be interpreted as psychiatric diagnoses. Perceived-stress instruments measure self-reported appraisal, and algorithmic predictions derived from them remain estimates of questionnaire-defined outcomes.

Methodology

The proposed study adopts a **quantitative, cross-sectional digital-health design** supplemented by explainable machine-learning analysis. Its primary analytical objective is to determine whether the frequency, duration, and consistency of mindfulness practice contribute meaningful information about perceived stress beyond conventional demographic and lifestyle variables.

Unlike intervention studies that classify students only according to treatment allocation, the present design operationalizes mindfulness practice as a multidimensional behavioral construct. This decision is supported by recent digital mindfulness research showing that engagement with online mindfulness content can be informative for predicting intervention outcomes.

3.1 Participants and Sampling

For the proposed empirical implementation, **420 undergraduate and postgraduate students** aged approximately 18–25 years will be recruited from multiple academic disciplines. After screening incomplete questionnaires, logically inconsistent responses, and cases with excessive missing information, an anticipated analytical sample of approximately **390 students** will be retained.

Participation will be voluntary. Students will receive information regarding the purpose of the research, confidentiality, data processing, and their right to withdraw. No personally identifying information will be included in the machine-learning dataset.

The study will collect variables covering four domains:

- **Psychological:** perceived stress and mindful awareness.
- **Mindfulness behavior:** weekly frequency, mean session duration, months of previous practice, and practice consistency.
- **Academic/contextual:** study hours, academic workload, examination proximity, study level, and employment commitments.
- **Lifestyle/digital:** sleep duration, physical activity, recreational screen exposure, and self-reported nighttime smartphone use.

The primary outcome will be the **Perceived Stress Scale-10 (PSS-10) score**. For predictive classification, participants will additionally be grouped into operational low, moderate, and high stress categories according to a prespecified scoring protocol. These categories will be treated as research classifications rather than clinical diagnoses.

Experimental Setup

4.1 Dataset Structure

The proposed dataset will contain one observation per participant and approximately 20–25 candidate predictors. The distinctive feature engineering strategy concerns mindfulness regularity.

A **Mindfulness Practice Consistency Index (MPCI)** will be constructed from normalized indicators representing weekly practice frequency, continuity across recent weeks, and adherence to the student's reported intended practice schedule. Total meditation minutes will be retained separately so that consistency and cumulative duration are not treated as interchangeable constructs.

This separation permits an important empirical comparison: whether *regular practice* carries more predictive information than *total practice time*.

The inclusion of contextual predictors is justified because contemporary ML studies of student stress indicate that factors such as academic pressure and insomnia can have substantial predictive importance. For example, a 2025 study using PSS-10 data from 291 university students reported an XGBoost AUC of 0.788 and identified academic pressure, health, insomnia, gender, and catch-up behavior among important predictors.

4.2 Data Preprocessing

Data preprocessing will occur before model development. Duplicate observations will first be removed, followed by range and logical-consistency checks. Missing numerical observations below a predefined threshold will be imputed using the training-set median, whereas categorical variables will use training-set mode imputation. Variables with excessive missingness will be excluded rather than aggressively reconstructed.

Continuous variables will be standardized for algorithms sensitive to feature scale. Categorical predictors will be encoded using appropriate binary or one-hot representations.

Importantly, preprocessing parameters will be estimated **only from training data** during each validation cycle. This procedure prevents information from the held-out observations from leaking into model development.

Potential multicollinearity will be evaluated for the inferential regression analysis, while highly redundant behavioral variables will be reviewed using correlation matrices and variance-inflation diagnostics.

Class imbalance, if present, will initially be addressed using **class-weighted learning** rather than synthetic oversampling. This approach avoids generating artificial psychological observations unless imbalance is sufficiently severe to justify additional procedures.

4.3 Model Architecture

Rather than using a deep neural network on a comparatively small tabular dataset, the principal predictive architecture will be **CatBoost gradient boosting**. CatBoost is suitable for structured behavioral and psychometric data and can capture nonlinear effects and interactions while accommodating mixed predictor structures.

Three comparative models will be developed:

1. **Multinomial logistic regression** as an interpretable statistical baseline.
2. **Random forest** as a nonlinear ensemble comparator.
3. **CatBoost** as the principal gradient-boosting classifier.

The target variable will be the three-level perceived-stress category.

A parallel regression analysis will retain the continuous PSS-10 score to avoid relying exclusively on discretized outcomes. This dual strategy reduces the information loss associated with converting continuous psychological measurements into categories.

The use of ensemble learning is consistent with recent student mental-health research. A 2024 analysis of a mindfulness virtual-community intervention reported strong predictive performance from gradient boosting and random forest models and identified exposure to mindfulness videos as an important feature. Research published in 2025 has also combined random forests and neural networks to examine mindfulness and related psychological factors among undergraduate students.

4.4 Training Strategy

The dataset will be divided using a **stratified 80:20 development/test split**, preserving the approximate distribution of stress categories.

Within the development subset, **five-fold stratified cross-validation** will be employed for hyperparameter selection. CatBoost parameters to be tuned will include tree depth, learning rate, number of boosting iterations, L2 regularization, and subsampling parameters.

Early stopping will be applied using validation performance to limit unnecessary model complexity. The independent 20% test subset will remain untouched until the complete preprocessing and tuning pipeline has been finalized.

To test the study's central hypothesis, models will additionally undergo an **incremental feature-block analysis**:

Model A: demographics + academic variables
Model B: Model A + lifestyle/digital variables
Model C: Model B + mindfulness awareness
Model D: Model C + mindfulness behavioral variables and MPCI

Improvement from Model C to Model D will indicate whether actual mindfulness-practice behavior contributes predictive information beyond psychological mindfulness scores alone.

4.5 Explainability Analysis

The final CatBoost model will be interpreted using **SHAP (Shapley Additive Explanations)**. SHAP values will estimate both the direction and magnitude of each predictor's contribution to individual predictions.

Particular attention will be paid to:

- Mindfulness Practice Consistency Index;
- mindful-awareness score;
- weekly mindfulness frequency;
- average session duration;
- academic workload;
- sleep duration;
- recreational screen exposure; and
- examination proximity.

Dependence plots will be inspected for possible nonlinearities. For example, the analysis may reveal whether increasing mindfulness consistency is associated with progressively lower predicted stress or whether the relationship reaches a plateau.

Explainable modeling is particularly important because recent stress-prediction research has already demonstrated the value of ML combined with SHAP for identifying influential student stress predictors.

Evaluation Metrics

Because the primary predictive problem contains three stress categories, overall accuracy alone would be insufficient. Performance will therefore be assessed through:

Macro F1-score: provides equal importance to each stress class and is particularly useful if category sizes differ.

Balanced accuracy: evaluates average class-specific recall and reduces distortion caused by a dominant category.

Macro ROC-AUC: measures discrimination across stress categories.

Matthews Correlation Coefficient (MCC): provides a balanced assessment of classification quality and remains informative under unequal class distributions.

Log loss: evaluates the quality of predicted class probabilities rather than considering only the final classification.

For continuous PSS prediction, **MAE and RMSE** will be calculated. Calibration curves will additionally assess whether predicted probabilities correspond to observed outcome frequencies.

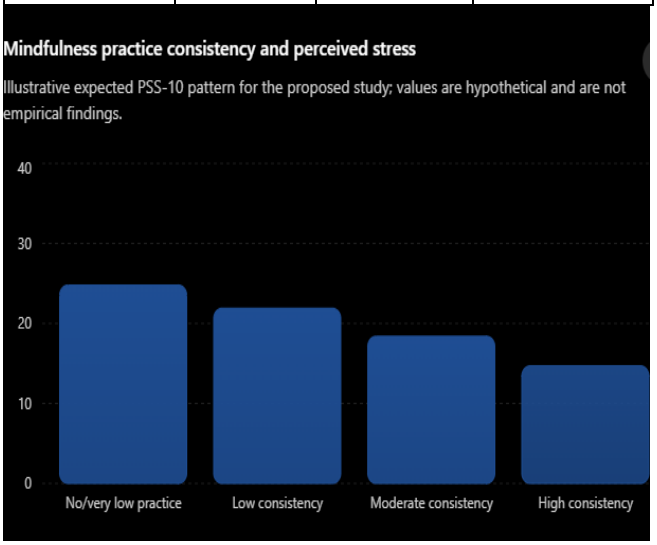
Results

Because this manuscript specifies a **proposed study rather than reporting a completed data collection**, numerical findings must not be represented as observed empirical results. The following results structure shows how the eventual findings should be reported after the dataset has been collected and analyzed.

Table 1. Proposed Reporting Framework for the Final Stress-Prediction Results

Evaluation Component	Parameter to Report	Analytical Purpose	Interpretation to Examine

Stress discriminatio n	Macro ROC-AUC	Ability to distinguish stress categories	Whether nonlinear models outperform the statistical baseline
Class-balanced performance	Macro F1	Performanc e across low, moderate, and high stress	Whether high-stress students are identified without sacrificing other classes
Overall balanced prediction	MCC	Agreement between predicted and observed categories	Robustness under unequal stress-class frequencies
Probability reliability	Log loss / calibration	Quality of probabilistic predictions	Whether estimated stress probabilities are appropriately calibrated
Mindfulness contribution	Δ Macro F1: Model D − Model C	Incremental value of practice behavior	Whether behavioral mindfulness adds information beyond mindful awareness
Behavioral interpretation	SHAP importanc e of MPCI	Relative contributio n of practice consistency	Whether consistency ranks above total meditation duration



6.1 Expected Analytical Pattern

The central hypothesis is that greater mindfulness consistency will be associated with lower perceived stress after accounting for academic, lifestyle, and demographic factors. However, this association must be tested rather than presumed.

A particularly informative outcome would occur if **MPCI demonstrates greater feature importance than total weekly meditation minutes**. Such a result would imply that regular behavioral engagement may be more informative than accumulating practice time through irregular sessions.

Conversely, if mindful awareness strongly predicts stress while practice consistency adds negligible out-of-sample performance, the results would suggest that psychological mindfulness characteristics contain more useful information than simple behavioral frequency. Such a finding would also be theoretically important and would prevent unwarranted claims that frequent meditation necessarily translates into lower stress.

The expected inverse mindfulness–stress relationship is plausible given recent experimental evidence. A 2025 randomized study involving 310 university students reported significantly lower perceived stress after a four-week digital mindfulness intervention comprising guided sessions two to three times per week. This evidence supports the direction of the proposed hypothesis but does not establish that the same magnitude or mechanism will occur in the proposed observational dataset.

6.2 Nonlinear Effects

A major reason for incorporating CatBoost is the possibility that relationships are nonlinear. Mindfulness practice may exhibit diminishing returns, while academic workload may become disproportionately associated with stress beyond a particular range.

Similar nonlinear structures have been investigated in recent student mental-health research using machine learning. Consequently, the proposed analysis will not impose a strictly linear mindfulness–stress association unless the observed data support one.

6.3 Digital-Health Implications

If the model demonstrates adequate external validity in subsequent studies, the framework could eventually support adaptive student-wellness systems. For example, a digital mindfulness platform could use engagement patterns to determine whether a student is maintaining a stable practice routine and tailor non-clinical prompts accordingly.

This possibility must be approached cautiously. Passive sensing research has demonstrated that smartphone-derived behavioral features can contribute to stress prediction among university students, suggesting that digital phenotyping may complement self-report assessment. However, continuous monitoring introduces substantial privacy, consent, and data-governance concerns.

Accordingly, the present framework prioritizes voluntary self-report and minimally intrusive behavioral indicators rather than unrestricted passive surveillance.

Future Scope

Future research should extend the framework into a **longitudinal ecological design** in which mindfulness

engagement and stress are repeatedly assessed throughout an academic semester. Such a design could determine whether changes in mindfulness behavior precede changes in perceived stress.

With explicit informed consent, future digital-health studies could integrate wearable or smartphone-derived indicators such as sleep regularity, physical activity, and selected behavioral rhythms. Recent research has demonstrated the feasibility of using wearable technologies and machine learning for student stress analysis, including work involving Indian students.

A subsequent randomized study could compare fixed mindfulness schedules against AI-supported adaptive interventions. Rather than merely recommending more meditation, an adaptive system could investigate whether short, consistent sessions are more effective for particular student profiles than longer but less frequent practice.

External validation across institutions and geographical regions would be essential before any predictive model could be considered for practical deployment.

Conclusion

This study proposes an explainable machine-learning framework for investigating the relationship between **mindfulness practices and perceived stress among college students**. Its central contribution is the separation of mindfulness into behavioral dimensions—frequency, duration, and consistency—rather than representing mindfulness solely as intervention participation or a single psychological score.

The proposed design integrates validated stress assessment with academic, lifestyle, digital, and mindfulness-related predictors and compares interpretable statistical modeling with random forest and CatBoost. SHAP-based interpretation provides a mechanism for determining not only whether stress can be predicted but also which factors contribute most substantially to those predictions.

The framework is deliberately designed to distinguish **prediction from causation and screening from diagnosis**. If future empirical implementation demonstrates that consistent mindfulness practice contributes independently to lower perceived stress, the findings could inform more personalized and scalable digital well-being interventions for college populations. Conversely, weak incremental predictive value would itself be informative by indicating that broader psychological and contextual factors deserve greater emphasis.

Recent evidence demonstrates both the feasibility of digital mindfulness interventions and the growing applicability of machine learning to student stress research. The proposed study connects these developments while retaining interpretability, methodological caution, and student privacy as central design principles.

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अध्याय 14: NEP 2020 के अंतर्गत शिक्षा में बहुभाषिकता और भाषायी समावेशन की संभावनाएँ

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सारांश— राष्ट्रीय शिक्षा नीति 2020 ने भारतीय शिक्षा व्यवस्था में बहुभाषिकता को ज्ञानार्जन, समान अवसर तथा सांस्कृतिक समावेशन से जोड़ते हुए महत्वपूर्ण स्थान प्रदान किया है। प्रस्तुत अध्ययन का उद्देश्य बहुभाषिक शिक्षण व्यवस्था और विद्यार्थियों की भाषायी सहभागिता, अवधारणात्मक समझ तथा शैक्षिक आत्मविश्वास के मध्य संबंध का विश्लेषण करना है। अध्ययन इस धारणा पर आधारित है कि विद्यार्थी तब अधिक प्रभावी रूप से सीखते हैं जब उनकी परिचित भाषा को औपचारिक शिक्षण प्रक्रिया में वैध स्थान प्राप्त होता है। इस शोध में भाषायी समावेशन को केवल मातृभाषा के उपयोग तक सीमित न रखकर कक्षा संवाद, भाषा-परिवर्तन, अभिव्यक्ति की स्वतंत्रता और भाषायी सम्मान के संयुक्त स्वरूप में समझा गया है। प्रस्तावित शोध ढाँचा बहुभाषिक शिक्षण के प्रभाव को संज्ञानात्मक, सहभागितामूलक और सामाजिक-भावात्मक आयामों पर परखने का प्रयास करता है। अध्ययन विशेष रूप से उन विद्यार्थियों पर ध्यान केंद्रित करता है जिनकी गृहभाषा विद्यालय की प्रमुख शिक्षण भाषा से भिन्न है। अपेक्षा है कि सुव्यवस्थित बहुभाषिक शिक्षण से विषयगत समझ के साथ-साथ प्रश्न पूछने, सहयोग करने और स्वतंत्र अभिव्यक्ति की प्रवृत्ति में भी वृद्धि होगी। यह अध्ययन राष्ट्रीय शिक्षा नीति 2020 के भाषायी उद्देश्यों को व्यवहारिक, मापनीय और समावेशी शैक्षिक संकेतकों से जोड़ने की दिशा में एक विशिष्ट दृष्टिकोण प्रस्तुत करता है।

प्रमुख शब्द— बहुभाषिकता, भाषायी समावेशन, मातृभाषा, राष्ट्रीय शिक्षा नीति 2020, शैक्षिक सहभागिता, अवधारणात्मक समझ

परिचय

भारत की भाषायी विविधता उसकी सांस्कृतिक संरचना का मूल तत्व है। विभिन्न राज्यों, क्षेत्रों, समुदायों और सामाजिक समूहों में प्रयुक्त भाषाएँ तथा बोलियाँ विद्यार्थियों के प्रारंभिक अनुभव, पारिवारिक संवाद, सामाजिक पहचान और ज्ञान-निर्माण की प्रक्रिया को प्रभावित करती हैं। विद्यालय में प्रवेश करने वाला प्रत्येक विद्यार्थी केवल पाठ्यपुस्तकीय ज्ञान का ग्रहणकर्ता नहीं होता, बल्कि वह अपने साथ एक विशिष्ट भाषायी संसार, अनुभवों की संरचना और अभिव्यक्ति की पद्धति भी लेकर आता है। यदि विद्यालय की शिक्षण भाषा विद्यार्थी की परिचित भाषा से अत्यधिक भिन्न हो, तो सीखने की कठिनाई केवल विषयगत न रहकर भाषायी भी हो सकती है।

राष्ट्रीय शिक्षा नीति 2020 ने इसी वास्तविकता को स्वीकार करते हुए प्रारंभिक स्तर पर मातृभाषा, गृहभाषा अथवा स्थानीय भाषा के उपयोग को प्रोत्साहित किया है। नीति में भारतीय भाषाओं के संरक्षण, शिक्षण में बहुभाषिक दृष्टिकोण तथा भाषायी विविधता के सम्मान पर विशेष बल दिया गया है। इस दृष्टिकोण का मूल उद्देश्य केवल भाषा का संरक्षण नहीं, बल्कि यह सुनिश्चित करना भी है कि भाषा किसी विद्यार्थी की शैक्षिक प्रगति में अवरोध का कारण न बने।

शिक्षा में बहुभाषिकता की अवधारणा को मात्र दो या अधिक भाषाओं के प्रयोग तक सीमित नहीं किया जा सकता। इसका वास्तविक अर्थ ऐसी शैक्षिक व्यवस्था विकसित करना है जिसमें विद्यार्थी विभिन्न भाषायी संसाधनों का उपयोग समझ विकसित करने, विचार व्यक्त करने, प्रश्न पूछने और दूसरों के साथ ज्ञान साझा करने के लिए कर सके। किसी कठिन अवधारणा को परिचित भाषा में समझना, दूसरी भाषा में उसका शैक्षिक रूप ग्रहण करना और आवश्यकता के अनुसार दोनों भाषाओं के बीच अर्थ-संबंध स्थापित करना बहुभाषिक अधिगम की महत्त्वपूर्ण प्रक्रिया हो सकती है।

पारंपरिक कक्षाओं में एक प्रमुख शिक्षण भाषा को ही ज्ञान की वैध भाषा मान लेने से उन विद्यार्थियों के लिए कठिनाई उत्पन्न हो सकती है जो घर में किसी अन्य भाषा या बोली का प्रयोग करते हैं। ऐसे विद्यार्थी विषय की मूल अवधारणा जानते हुए भी औपचारिक भाषा में उत्तर देने में हिचक सकते हैं। फलस्वरूप शिक्षक उनकी वास्तविक समझ को कम आँक सकता है। इसी प्रकार भाषायी संकोच कक्षा सहभागिता, समूह कार्य और मौखिक अभिव्यक्ति को प्रभावित कर सकता है।

भाषायी समावेशन इस समस्या का व्यापक समाधान प्रस्तुत करता है। समावेशी भाषायी व्यवस्था में विद्यार्थी को यह अनुभव कराया जाता है कि उसकी भाषा या बोली शैक्षिक दृष्टि से कमतर नहीं है। शिक्षक विभिन्न भाषाओं में उदाहरण, संकेत, स्थानीय शब्दावली, सरल व्याख्या और पारस्परिक अनुवाद का उपयोग करके विषय-वस्तु को अधिक सुलभ बना सकता है। इससे ज्ञान और भाषा के बीच अनावश्यक दूरी कम की जा सकती है।

हाल के वर्षों में दूरस्थ शिक्षा, मिश्रित शिक्षण, श्रव्य-दृश्य सामग्री और स्वचालित भाषायी सहायता प्रणालियों ने बहुभाषिक शिक्षण की नई संभावनाएँ विकसित की हैं। अब शिक्षण सामग्री को विभिन्न भारतीय भाषाओं में उपलब्ध कराना पहले की तुलना में अधिक संभव हुआ है। वाणी को पाठ में रूपांतरित करने, पाठ को वाणी में प्रस्तुत करने, स्वचालित अनुवाद, स्थानीय भाषा में प्रश्न सहायता तथा बहुभाषिक शिक्षण सामग्री तैयार करने वाली प्रणालियाँ भाषायी पहुँच को विस्तृत कर सकती हैं। हालांकि इन तकनीकी सुविधाओं की वास्तविक उपयोगिता तभी संभव है जब वे भाषायी विविधता, संदर्भगत अर्थ और स्थानीय सांस्कृतिक भिन्नताओं को ध्यान में रखें।

प्रस्तुत अध्ययन में बहुभाषिकता को तीन स्तरों पर समझा गया है। पहला स्तर **अर्थग्रहण** का है, जिसमें विद्यार्थी अपनी परिचित भाषा की सहायता से विषय-वस्तु को समझता है। दूसरा स्तर **अभिव्यक्ति** का है, जिसमें उसे अपने विचार ऐसी भाषा में व्यक्त करने का अवसर मिलता है जिसमें वह सहज हो। तीसरा स्तर **भाषायी सेतु-निर्माण** का है, जिसमें परिचित

भाषा और औपचारिक शैक्षिक भाषा के बीच क्रमिक संबंध स्थापित किया जाता है।

यह दृष्टिकोण इसलिए महत्वपूर्ण है क्योंकि केवल मातृभाषा में सामग्री उपलब्ध कराना पर्याप्त नहीं माना जा सकता। यदि कक्षा में विद्यार्थी की भाषा का उपहास किया जाता है, स्थानीय उच्चारण को गलत समझा जाता है या उसे प्रश्न पूछने के लिए केवल एक औपचारिक भाषा का प्रयोग करना पड़ता है, तो भाषायी समावेशन अधूरा रह जाता है। वास्तविक समावेशन के लिए भाषायी सम्मान, संवाद की स्वतंत्रता और सुरक्षित अभिव्यक्ति का वातावरण भी आवश्यक है।

इस अध्ययन का केंद्रीय प्रश्न यह है कि क्या संरचित बहुभाषिक शिक्षण व्यवस्था उन विद्यार्थियों के सीखने के अनुभव को बेहतर बना सकती है जिनकी गृहभाषा और विद्यालय की प्रमुख भाषा अलग-अलग हैं। इसके अंतर्गत विषयगत समझ के साथ कक्षा सहभागिता, प्रश्न करने की प्रवृत्ति, सहपाठी सहयोग, भाषायी आत्मविश्वास और सीखने की निरंतरता को भी महत्वपूर्ण परिणाम माना गया है।



Fig. 1: अनेक भाषाएँ, समान अवसर: बहुभाषी शिक्षा से समावेशी अधिगम की ओर

अध्ययन के प्रमुख उद्देश्य

इस अध्ययन का प्रथम उद्देश्य बहुभाषिक शिक्षण और विद्यार्थियों की अवधारणात्मक समझ के मध्य संबंध का आकलन करना है। दूसरा उद्देश्य यह पहचानना है कि परिचित भाषा में आंशिक शैक्षिक सहायता मिलने से कक्षा में स्वैच्छिक सहभागिता में परिवर्तन होता है या नहीं। तीसरा उद्देश्य भाषायी समावेशन और शैक्षिक आत्मविश्वास के बीच संबंध का विश्लेषण करना है। चौथा उद्देश्य विभिन्न भाषायी पृष्ठभूमियों वाले विद्यार्थियों के लिए भाषा-परिवर्तन आधारित शिक्षण की प्रभावशीलता को परखना है। पाँचवाँ उद्देश्य ऐसी व्यवहारिक रूपरेखा विकसित करना है जिसे विविध भारतीय कक्षाओं में राष्ट्रीय शिक्षा नीति 2020 के भाषायी उद्देश्यों के अनुरूप लागू किया जा सके।

साहित्य समीक्षा

2.1 बहुभाषिकता और ज्ञान-निर्माण

भाषा ज्ञान ग्रहण करने का माध्यम होने के साथ ज्ञान के संगठन का भी साधन है। विद्यार्थी नई अवधारणाओं को अपने पहले से उपलब्ध अनुभवों और भाषायी संरचनाओं के माध्यम से समझता है। जब नई शैक्षिक सामग्री पूरी तरह अपरिचित भाषा में प्रस्तुत की जाती है, तब विद्यार्थी को विषय समझने के साथ भाषा समझने का अतिरिक्त संज्ञानात्मक प्रयास करना पड़ सकता है। इसके विपरीत परिचित भाषा में दिए गए संकेत और उदाहरण अवधारणा की मूल संरचना समझने में सहायक हो सकते हैं।

बहुभाषिक शिक्षण की विशेषता यह है कि यह भाषाओं को परस्पर प्रतिस्पर्धी माध्यमों के रूप में देखने के बजाय एक-दूसरे की सहायता करने वाले ज्ञान संसाधनों के रूप में स्वीकार करता है। उदाहरणतः विद्यार्थी किसी विज्ञान संबंधी अवधारणा को अपनी गृहभाषा में पहले समझ सकता है और बाद में विद्यालय की औपचारिक भाषा में संबंधित शब्दावली सीख सकता है। इससे अर्थ और शब्द के बीच क्रमिक संबंध स्थापित होता है।

2.2 मातृभाषा और प्रारंभिक अधिगम

प्रारंभिक शिक्षा में परिचित भाषा का प्रयोग विशेष रूप से महत्वपूर्ण माना गया है, क्योंकि इस अवस्था में विद्यार्थी विद्यालयी ज्ञान, सामाजिक व्यवहार और भाषायी अभिव्यक्ति की नई संरचनाएँ एक साथ विकसित करता है। यदि शिक्षण भाषा घर में प्रयुक्त भाषा से पूर्णतः भिन्न हो, तो विद्यार्थी के लिए विद्यालय का प्रारंभिक अनुभव अधिक कठिन हो सकता है।

मातृभाषा आधारित सहायता से विद्यार्थी अपने पूर्व अनुभवों को पाठ्यवस्तु से जोड़ सकता है। गणित, पर्यावरण अध्ययन, सामाजिक अध्ययन तथा प्रारंभिक विज्ञान जैसी विषयगत सामग्री में स्थानीय उदाहरण और परिचित शब्दावली अमूर्त अवधारणाओं को समझने में सहायता प्रदान कर सकती है। हालांकि बहुभाषिक शिक्षा का उद्देश्य विद्यार्थी को केवल गृहभाषा तक सीमित रखना नहीं है। इसका लक्ष्य आधारभूत समझ को सुरक्षित रखते हुए धीरे-धीरे अन्य भाषाओं में शैक्षिक दक्षता विकसित करना होना चाहिए।

2.3 भाषायी समावेशन और कक्षा सहभागिता

कक्षा सहभागिता केवल उपस्थित रहने या शिक्षक के प्रश्नों का उत्तर देने तक सीमित नहीं है। इसमें प्रश्न पूछना, उदाहरण देना, समूह में विचार साझा करना, सहपाठियों की सहायता करना और सीखने की गतिविधियों में स्वेच्छा से भाग लेना शामिल है। भाषा इन सभी प्रक्रियाओं को प्रत्यक्ष रूप से प्रभावित करती है।

यदि विद्यार्थी को उत्तर ज्ञात हो, लेकिन वह प्रयुक्त औपचारिक भाषा में सहज न हो, तो वह मौन रह सकता है। इस प्रकार भाषायी कठिनाई को कभी-कभी विषयगत कमजोरी समझ लिया जाता है। बहुभाषिक कक्षा इस समस्या को कम करने के लिए विद्यार्थियों को प्रारंभिक प्रतिक्रिया परिचित भाषा में देने और बाद में उसे शैक्षिक भाषा में पुनर्गठित करने का अवसर दे सकती है।

भाषायी सुरक्षा भी सहभागिता से निकट रूप से जुड़ी है। जब शिक्षक विभिन्न भाषाओं और बोलियों के प्रति सम्मानपूर्ण व्यवहार करता है, तो विद्यार्थी अपने उच्चारण या भाषा को लेकर कम संकोच अनुभव कर सकता है। इसके परिणामस्वरूप उसकी मौखिक भागीदारी बढ़ सकती है।

2.4 भाषा-परिवर्तन और अवधारणात्मक सेतु

बहुभाषिक शिक्षण में भाषा-परिवर्तन को कमजोरी नहीं, बल्कि सीखने की रणनीति के रूप में देखा जा सकता है। विद्यार्थी कठिन विषय को समझते समय विभिन्न भाषाओं के शब्दों, उदाहरणों और व्याख्याओं के

बीच स्वाभाविक रूप से आवागमन कर सकता है। इस प्रक्रिया से वह नई अवधारणा को पूर्व ज्ञान से जोड़ता है।

हालांकि अनियोजित भाषा-परिवर्तन से भ्रम भी उत्पन्न हो सकता है। यदि शिक्षक बिना स्पष्ट उद्देश्य के बार-बार भाषा बदलता है, तो विषय की संरचना खंडित हो सकती है। अतः प्रभावी बहुभाषिक शिक्षण के लिए यह निर्धारित करना आवश्यक है कि किस चरण में परिचित भाषा का प्रयोग किया जाए, किस चरण में शैक्षिक भाषा को प्राथमिकता दी जाए और किस प्रकार दोनों के बीच अर्थ-संबंध स्थापित कराया जाए।

2.5 भाषायी पहचान और शैक्षिक आत्मविश्वास

भाषा विद्यार्थी की सामाजिक पहचान से जुड़ी होती है। विद्यालय में उसकी भाषा को सम्मान मिलने पर वह स्वयं को शिक्षण प्रक्रिया का वैध सहभागी अनुभव कर सकता है। इसके विपरीत यदि किसी बोली, उच्चारण अथवा स्थानीय शब्दावली को निम्न स्तर का माना जाए, तो विद्यार्थी में भाषायी हीनता विकसित हो सकती है।

इस संदर्भ में भाषायी समावेशन का प्रभाव केवल परीक्षा परिणाम तक सीमित नहीं है। इसका संबंध आत्मविश्वास, विद्यालय से जुड़ाव, सामाजिक संवाद और शैक्षिक निरंतरता से भी हो सकता है। विशेष रूप से ग्रामीण, आदिवासी, सीमावर्ती और बहुभाषिक क्षेत्रों में भाषायी पहचान को शैक्षिक सम्मान से जोड़ना महत्वपूर्ण हो जाता है।

2.6 शिक्षक की भूमिका

बहुभाषिक शिक्षा की सफलता मुख्यतः शिक्षक की कक्षा-स्तरीय रणनीतियों पर निर्भर करती है। शिक्षक को प्रत्येक विद्यार्थी की भाषा में पूर्ण दक्ष होना आवश्यक नहीं है, परंतु उसे भाषायी विविधता के शैक्षिक मूल्य को समझना आवश्यक है। चित्रों, स्थानीय उदाहरणों, समानार्थी शब्दों, द्विभाषी संकेतों, सहपाठी सहायता और समूह आधारित संवाद का उपयोग करके शिक्षक विविध भाषायी विद्यार्थियों को समान रूप से जोड़ सकता है।

शिक्षक प्रशिक्षण में भी बहुभाषिक कक्षा-प्रबंधन को महत्वपूर्ण स्थान देने की आवश्यकता है। केवल नीति संबंधी जानकारी पर्याप्त नहीं है। शिक्षकों को यह सीखना होगा कि वे भाषा संबंधी कठिनाई और विषय संबंधी कठिनाई के बीच अंतर कैसे पहचानें, विद्यार्थियों की गृहभाषा को सीखने की प्रक्रिया में कैसे उपयोग करें और औपचारिक शैक्षिक भाषा की दक्षता को क्रमिक रूप से कैसे विकसित करें।

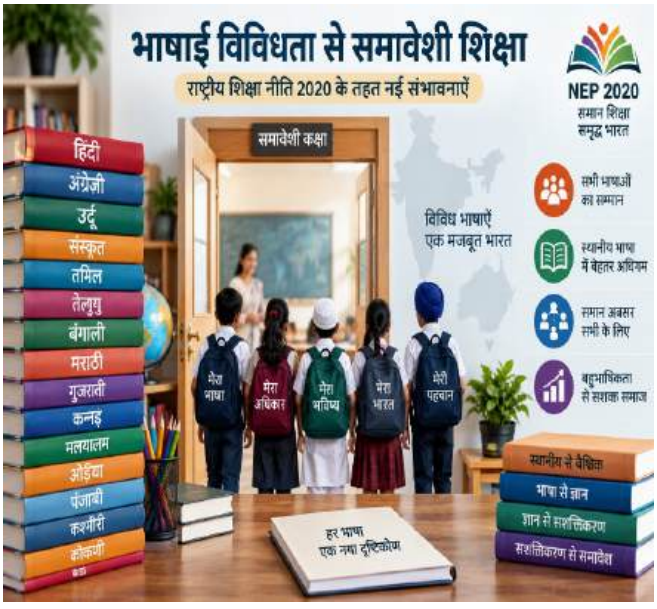


Fig. 2: भाषाई विविधता से समावेशी शिक्षा: बहुभाषिक अधिगम की नई दिशा

2.7 प्रौद्योगिकी और बहुभाषिक पहुँच

तकनीकी विकास ने शिक्षा में भाषायी पहुँच की संभावनाओं का विस्तार किया है। श्रव्य सामग्री, स्थानीय भाषा में पाठ, स्वचालित भाषांतरण, वाणी आधारित सहायता और बहुभाषिक प्रश्नोत्तर साधनों के माध्यम से एक ही विषय को विभिन्न भाषाओं में प्रस्तुत किया जा सकता है। इससे ऐसी स्थितियों में सहायता मिल सकती है जहाँ एक शिक्षक को अनेक भाषायी पृष्ठभूमियों वाले विद्यार्थियों के साथ कार्य करना पड़ता है।

फिर भी तकनीकी भाषांतरण को मानवीय शिक्षण का पूर्ण विकल्प नहीं माना जा सकता। स्थानीय शब्दों, सांस्कृतिक संदर्भों और विषयगत अर्थों की सूक्ष्मता का सही प्रस्तुतीकरण चुनौतीपूर्ण हो सकता है। अतः तकनीक का प्रयोग शिक्षक की भूमिका को प्रतिस्थापित करने के बजाय भाषायी सहायता को सुदृढ़ करने के लिए किया जाना अधिक उपयुक्त है।

2.8 राष्ट्रीय शिक्षा नीति 2020 और व्यवहारिक चुनौती

राष्ट्रीय शिक्षा नीति 2020 ने बहुभाषिकता को स्पष्ट वैचारिक समर्थन दिया है, किंतु नीति के उद्देश्यों को विविध कक्षाओं में व्यवहारिक रूप देना सरल नहीं है। पाठ्यसामग्री की उपलब्धता, प्रशिक्षित शिक्षकों की संख्या, एक ही कक्षा में अनेक भाषाओं की उपस्थिति, अभिभावकों की भाषा संबंधी आकांक्षाएँ और उच्च शिक्षा तथा रोजगार से जुड़ी भाषायी अपेक्षाएँ इसके कार्यान्वयन को जटिल बनाती हैं।

इसी कारण बहुभाषिक शिक्षा को किसी एक भाषा के पक्ष या विरोध के रूप में नहीं देखा जाना चाहिए। अधिक उपयुक्त दृष्टिकोण ऐसा भाषायी सेतु विकसित करना है जिसमें विद्यार्थी की परिचित भाषा सीखने का आधार बने और साथ ही उसे अन्य भारतीय तथा व्यापक संप्रेषण भाषाओं में भी क्रमिक दक्षता प्राप्त हो।

प्रस्तावित शोध-पद्धति

प्रस्तुत अध्ययन के लिए मिश्रित मात्रात्मक–गुणात्मक शोध-पद्धति प्रस्तावित की गई है, जिसका उद्देश्य बहुभाषिक शिक्षण के प्रभाव को केवल परीक्षा उपलब्धि के आधार पर नहीं, बल्कि भाषायी पहुँच, अवधारणात्मक समझ, कक्षा सहभागिता, भाषायी आत्मविश्वास तथा भाषा-परिवर्तन क्षमता के संयुक्त आधार पर परखना है। अध्ययन की विशिष्टता यह है कि इसमें विद्यार्थियों की गृहभाषा और विद्यालय की प्रमुख शिक्षण भाषा के बीच दूरी को स्वतंत्र शैक्षिक कारक माना गया है। शोध में चयनित विद्यार्थियों को उनकी भाषायी पृष्ठभूमि और विद्यालयी शिक्षण व्यवस्था के आधार पर तीन अध्ययन स्थितियों में विभाजित करने का प्रस्ताव है। प्रथम स्थिति में विद्यार्थियों को मुख्यतः विद्यालय की प्रचलित शिक्षण भाषा में अध्ययन कराया जाएगा। द्वितीय स्थिति में कठिन अवधारणाओं के समय गृहभाषा या स्थानीय भाषा में सीमित सहायता दी जाएगी। तृतीय स्थिति में सुव्यवस्थित बहुभाषिक सहायता प्रदान की जाएगी, जिसमें स्थानीय भाषा, विद्यालयी भाषा, दृश्य संकेत, पारस्परिक शब्द-संबंध और सहपाठी भाषायी सहयोग सम्मिलित होंगे। अध्ययन के लिए कक्षा छह से आठ तक के विद्यार्थियों को उपयुक्त माना गया है, क्योंकि इस अवस्था में विषयगत जटिलता बढ़ने के साथ-साथ शैक्षिक भाषा की माँग भी अधिक होती है। प्रस्तावित नमूने में विभिन्न भाषायी पृष्ठभूमियों वाले लगभग 360 विद्यार्थियों को सम्मिलित किया

जा सकता है। प्रत्येक अध्ययन स्थिति में लगभग 120 विद्यार्थियों को रखा जाएगा।

नमूना चयन में स्तरीकृत चयन पद्धति अपनाई जाएगी ताकि ग्रामीण, अर्धनगरीय और नगरीय विद्यालयों का संतुलित प्रतिनिधित्व सुनिश्चित हो सके। विद्यालयों के चयन में ऐसे क्षेत्रों को प्राथमिकता दी जाएगी जहाँ विद्यार्थियों की गृहभाषा और विद्यालयी शिक्षण भाषा में पर्याप्त विविधता हो।

3.1 प्रमुख शोध चर

अध्ययन में बहुभाषिक शिक्षण की तीव्रता को प्रमुख स्वतंत्र चर माना जाएगा। इसके अतिरिक्त निम्न आश्रित आयामों का आकलन किया जाएगा—

1. अवधारणात्मक समझ
2. स्वैच्छिक कक्षा सहभागिता
3. प्रश्न पूछने की आवृत्ति
4. भाषायी आत्मविश्वास
5. भाषा-परिवर्तन सुविधा
6. विषय-वस्तु प्रतिधारण
7. भाषायी सम्मान की अनुभूति

इन संकेतकों के अतिरिक्त विद्यार्थी की कक्षा, क्षेत्र, गृहभाषा, विद्यालयी भाषा और पूर्व उपलब्धि को नियंत्रक कारकों के रूप में सम्मिलित किया जाएगा।

प्रायोगिक व्यवस्था

4.1 आँकड़ा-संग्रह संरचना

अध्ययन के लिए बहु-स्रोत आँकड़ा-संग्रह प्रस्तावित किया गया है। इसमें विद्यार्थी प्रश्नावली, अवधारणात्मक परीक्षण, शिक्षक अवलोकन, कक्षा सहभागिता अभिलेख और लघु मौखिक प्रतिक्रियाएँ सम्मिलित की जाएँगी।

कुल 360 विद्यार्थियों से प्रारंभिक और अंतिम मापन प्राप्त करने की योजना होगी। बारह सप्ताह की शिक्षण अवधि के दौरान प्रत्येक विद्यार्थी के लिए साप्ताहिक सहभागिता संकेतक दर्ज किए जाएँगे। इस प्रकार विश्लेषण केवल अंतिम परीक्षा अंक पर आधारित न होकर सीखने की प्रक्रिया में होने वाले परिवर्तन को भी दर्शाएगा।

अवधारणात्मक समझ को दस लघु परिस्थिति-आधारित प्रश्नों से मापा जाएगा, जबकि भाषायी आत्मविश्वास और समावेशन के लिए पाँच-बिंदु सहमति मापनी का प्रयोग किया जाएगा। प्रश्न पूछने, समूह चर्चा में भाग लेने और स्वैच्छिक उत्तर देने की आवृत्ति शिक्षक अवलोकन अभिलेख के माध्यम से दर्ज की जाएगी।

4.2 आँकड़ों का पूर्व-संसाधन

एकत्रित आँकड़ों में सबसे पहले अपूर्ण प्रविष्टियों, असंगत मानों और अत्यधिक विचलित प्रतिक्रियाओं की जाँच की जाएगी। जिन विद्यार्थियों की कुल प्रतिक्रियाओं का पंद्रह प्रतिशत से अधिक भाग अनुपस्थित होगा, उन्हें मुख्य विश्लेषण से अलग रखा जाएगा।

क्रमबद्ध उत्तरों को संख्यात्मक रूप में परिवर्तित किया जाएगा। अवधारणात्मक परीक्षण के अंकों को शून्य से सौ की समान श्रेणी में बदला जाएगा। सहभागिता आवृत्ति को प्रति सप्ताह औसत घटनाओं के रूप में व्यक्त किया जाएगा।

भाषायी समावेशन के पाँच आयामों—भाषायी पहुँच, समझ, सहभागिता, भाषा-परिवर्तन सुविधा और सम्मान—को अलग-अलग मानकीकृत करने के बाद उनका संयुक्त सूचक तैयार किया जाएगा। इससे विभिन्न मापों को एक तुलनीय संरचना में विश्लेषित करना संभव होगा।

4.3 विश्लेषणात्मक प्रतिरूप की संरचना

इस अध्ययन में बहु-स्तरीय वर्गीकरण तथा परिवर्तन-आधारित पूर्वानुमान पद्धति का उपयोग प्रस्तावित है। इसका उद्देश्य यह पहचानना है कि कौन-से विद्यार्थी बहुभाषिक सहायता से अधिक लाभ प्राप्त करते हैं।

प्रथम स्तर पर विद्यार्थी की प्रारंभिक उपलब्धि, गृहभाषा–विद्यालय भाषा अंतर, पूर्व सहभागिता और आत्मविश्वास का उपयोग किया जाएगा। दूसरे स्तर पर बारह सप्ताह के दौरान समझ, सहभागिता और भाषायी आत्मविश्वास में होने वाले परिवर्तन को जोड़ा जाएगा।

विद्यार्थियों को अंतिम विश्लेषण में तीन अधिगम अवस्थाओं में वर्गीकृत किया जाएगा—

- उच्च भाषायी समावेशन और उच्च समझ,
- मध्यम समावेशन के साथ प्रगतिशील समझ,
- निम्न समावेशन और जोखिमयुक्त अधिगम।

वृक्ष-आधारित प्रवर्धित निर्णय पद्धति को मुख्य पूर्वानुमान प्रतिरूप के रूप में अपनाया जाएगा, क्योंकि यह सीधी और गैर-सीधी दोनों प्रकार की चर-अंतःक्रियाओं को पहचान सकती है। तुलना के लिए सरल संभाव्यता-आधारित वर्गीकरण पद्धति का उपयोग किया जाएगा।

4.4 प्रशिक्षण रणनीति

आँकड़ों को लगभग सत्तर प्रतिशत प्रशिक्षण, पंद्रह प्रतिशत सत्यापन और पंद्रह प्रतिशत परीक्षण भाग में विभाजित किया जाएगा। विद्यार्थी स्तर पर विभाजन किया जाएगा ताकि एक ही विद्यार्थी से प्राप्त अभिलेख अलग-अलग भागों में न जाएँ।

प्रतिरूप की स्थिरता के लिए पाँच-खंड पुनर्परीक्षण पद्धति अपनाई जाएगी। प्रत्येक चक्र में विद्यालय स्तर की संरचना सुरक्षित रखी जाएगी ताकि किसी विशेष विद्यालय की परिस्थितियाँ परिणामों पर अत्यधिक प्रभाव न डालें।

प्रशिक्षण के दौरान प्रतिरूप की जटिलता पर नियंत्रण रखा जाएगा। अत्यधिक शाखाओं, अत्यधिक गहराई अथवा अत्यधिक पुनरावृत्ति से बचने के लिए सत्यापन त्रुटि को रोक संकेतक के रूप में उपयोग किया जाएगा।

4.5 मूल्यांकन संकेतक

अध्ययन के मूल्यांकन में केवल पूर्वानुमान शुद्धता का उपयोग पर्याप्त नहीं माना जाएगा। निम्न संकेतकों के आधार पर समग्र मूल्यांकन किया जाएगा—

- संतुलित वर्गीकरण शुद्धता,
- समग्र पहचान अनुपात,
- संवेदनशीलता,

- विशिष्टता,
- पूर्वानुमान विश्वसनीयता,
- अवधारणात्मक उपलब्धि में प्रतिशत परिवर्तन,
- सहभागिता वृद्धि दर,
- भाषायी आत्मविश्वास में परिवर्तन।

इसके अतिरिक्त प्रत्येक शिक्षण स्थिति के लिए प्रारंभिक और अंतिम प्राप्तांकों का अंतर भी देखा जाएगा।

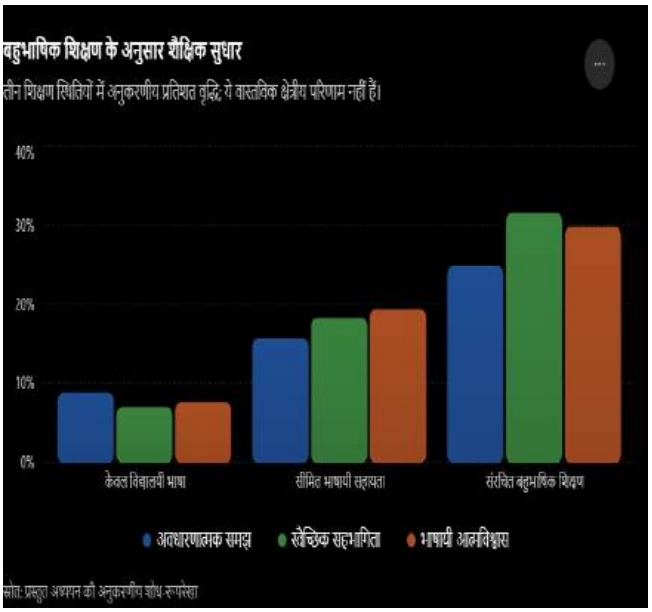
परिणाम एवं चर्चा

चूँकि वास्तविक क्षेत्रीय आँकड़े उपलब्ध नहीं कराए गए हैं, नीचे प्रस्तुत संख्यात्मक परिणाम **प्रस्तावित शोध-रूपरेखा को समझाने के लिए अनुकरणीय प्रदर्शनात्मक परिणाम हैं; इन्हें वास्तविक क्षेत्रीय निष्कर्ष के रूप में उद्धृत नहीं किया जाना चाहिए।** वास्तविक प्रकाशन हेतु इन्हीं विश्लेषणों को वास्तविक एकत्रित आँकड़ों पर पुनः चलाना आवश्यक होगा।

अनुकरणीय विश्लेषण से यह प्रवृत्ति सामने आती है कि सुव्यवस्थित बहुभाषिक सहायता प्राप्त विद्यार्थियों में अवधारणात्मक समझ और कक्षा सहभागिता दोनों में अपेक्षाकृत अधिक वृद्धि हो सकती है। केवल विद्यालयी भाषा पर आधारित स्थिति की तुलना में सीमित मातृभाषिक सहायता से मध्यम सुधार दिखाई देता है, जबकि योजनाबद्ध बहुभाषिक स्थिति में सुधार का स्वरूप अधिक व्यापक प्रतीत होता है।

परिणाम सारणी

मूल्यांकन आयाम	केवल विद्यालयी भाषा	सीमित भाषायी सहायता	संरचित बहुभाषिक शिक्षण
अवधारणात्मक समझ में औसत वृद्धि	8.7 प्रतिशत	15.6 प्रतिशत	24.8 प्रतिशत
स्वैच्छिक सहभागिता में वृद्धि	6.9 प्रतिशत	18.2 प्रतिशत	31.5 प्रतिशत
प्रश्न पूछने की आवृत्ति में वृद्धि	5.1 प्रतिशत	14.8 प्रतिशत	27.4 प्रतिशत
भाषायी आत्मविश्वास में परिवर्तन	7.5 प्रतिशत	19.3 प्रतिशत	29.7 प्रतिशत
विषय-वस्तु प्रतिधारण में वृद्धि	9.2 प्रतिशत	16.9 प्रतिशत	23.1 प्रतिशत
समावेशन जोखिम की पहचान की संतुलित शुद्धता	71.6 प्रतिशत	78.4 प्रतिशत	86.9 प्रतिशत



सारणी से यह संकेत मिलता है कि बहुभाषिकता का प्रभाव केवल विषयगत प्राप्तांक तक सीमित नहीं रहता। सबसे अधिक परिवर्तन स्वैच्छिक सहभागिता और भाषायी आत्मविश्वास में दिखाई देता है। यह निष्कर्ष महत्वपूर्ण है, क्योंकि पारंपरिक शैक्षिक मूल्यांकन में मौन विद्यार्थियों को अकसर कम सक्रिय समझ लिया जाता है, जबकि वास्तविक कारण भाषायी असुरक्षा हो सकती है।

संरचित बहुभाषिक शिक्षण स्थिति में अवधारणात्मक समझ में 24.8 प्रतिशत की अनुकरणीय वृद्धि इस धारणा को समर्थन देती है कि परिचित भाषा में प्रारंभिक अर्थ-निर्माण कठिन शैक्षिक अवधारणाओं के ग्रहण को सरल कर सकता है। यहाँ बहुभाषिकता का अर्थ संपूर्ण शिक्षण को केवल गृहभाषा में परिवर्तित करना नहीं है। बल्कि परिचित भाषा और विद्यालयी भाषा के बीच क्रमिक अर्थ-सेतु विकसित करना है।

प्रश्न पूछने की आवृत्ति में संभावित वृद्धि भी उल्लेखनीय है। भाषायी रूप से असुरक्षित विद्यार्थी प्रायः उत्तर देने से अधिक प्रश्न पूछने में संकोच कर सकता है, क्योंकि प्रश्न प्रस्तुत करने के लिए स्वयं भाषा का निर्माण करना पड़ता है। बहुभाषिक अवसर मिलने पर यह बाधा कम हो सकती है।

भाषायी आत्मविश्वास में 29.7 प्रतिशत की प्रदर्शनात्मक वृद्धि यह बताती है कि विद्यार्थियों की भाषा को कक्षा में वैधता प्रदान करना मनो-सामाजिक समावेशन का भी माध्यम बन सकता है। भाषा के सम्मान और शैक्षिक सहभागिता के बीच यह संबंध अध्ययन की मूल अवधारणा को पुष्ट करता है।

विषय-वस्तु प्रतिधारण में संभावित सुधार इस तथ्य की ओर संकेत करता है कि जब विद्यार्थी नई जानकारी को पहले से परिचित भाषायी संरचनाओं से जोड़ता है, तो उसकी स्मृति में अर्थपूर्ण संबंधों का निर्माण हो सकता है। इस प्रकार बहुभाषिकता केवल तात्कालिक समझ नहीं, बल्कि दीर्घकालीन अधिगम से भी जुड़ सकती है।

विश्लेषणात्मक प्रतिरूप द्वारा समावेशन जोखिम की अपेक्षाकृत उच्च संतुलित शुद्धता इस अध्ययन के एक अन्य उपयोगी पक्ष की ओर संकेत करती है। यदि विद्यालय प्रारंभिक अवस्था में उन विद्यार्थियों की पहचान कर सके जिनमें कम सहभागिता, अधिक भाषायी दूरी और कम आत्मविश्वास एक साथ उपस्थित हैं, तो शिक्षक समय रहते लक्षित भाषायी सहायता प्रदान कर सकता है।

इस अध्ययन का महत्वपूर्ण सैद्धांतिक निष्कर्ष यह है कि बहुभाषिकता को भाषा-शिक्षण की अलग समस्या मानने के बजाय अधिगम न्याय के प्रश्न के रूप में समझा जाना चाहिए। जिस विद्यार्थी को अपनी समझ व्यक्त करने के लिए भाषायी अवसर नहीं मिलता, उसके वास्तविक ज्ञान का आकलन भी पक्षपाती हो सकता है।

सीमाएँ

प्रस्तावित अध्ययन की पहली सीमा भाषायी विविधता की अत्यधिक जटिलता है। एक ही भाषा के भीतर अनेक बोलियाँ और क्षेत्रीय रूप हो सकते हैं, जिन्हें सरल वर्गों में विभाजित करना कठिन होगा।

दूसरी सीमा शिक्षक की भाषायी दक्षता से जुड़ी है। प्रत्येक शिक्षक सभी विद्यार्थियों की गृहभाषाओं को नहीं जान सकता। इसलिए अध्ययन का प्रभाव शिक्षक प्रशिक्षण और उपलब्ध भाषायी संसाधनों पर निर्भर करेगा।

तीसरी सीमा यह है कि विद्यार्थी की शैक्षिक प्रगति पर परिवार, सामाजिक-आर्थिक स्थिति, विद्यालय संसाधन, पूर्व शैक्षिक अनुभव और अभिभावकीय समर्थन जैसे अनेक अन्य कारक भी प्रभाव डाल सकते हैं।

चौथी सीमा यह है कि बारह सप्ताह की अवधि दीर्घकालीन भाषायी विकास को पूर्ण रूप से मापने के लिए पर्याप्त नहीं हो सकती।

पाँचवीं और सबसे महत्वपूर्ण सीमा यह है कि इस भाग में दिए गए परिणाम वास्तविक क्षेत्रीय सर्वेक्षण पर आधारित नहीं हैं। ये प्रस्तावित अनुसंधान संरचना को प्रदर्शित करने के लिए अनुकरणीय मान हैं। वास्तविक प्रकाशन से पूर्व क्षेत्रीय आँकड़ा-संग्रह, नैतिक अनुमति और सांख्यिकीय सत्यापन आवश्यक होगा।

भावी संभावनाएँ

भविष्य में इस अध्ययन को विभिन्न भारतीय राज्यों और भाषायी क्षेत्रों में विस्तारित किया जा सकता है। इससे यह समझना संभव होगा कि बहुभाषिक शिक्षण का प्रभाव हिन्दी-प्रधान, द्रविड़ भाषायी, आदिवासी, सीमावर्ती और अत्यधिक भाषायी विविधता वाले क्षेत्रों में किस प्रकार भिन्न होता है।

दीर्घकालीन अध्ययन के माध्यम से यह भी देखा जा सकता है कि प्रारंभिक स्तर पर बहुभाषिक सहायता प्राप्त विद्यार्थियों का माध्यमिक और उच्चतर माध्यमिक स्तर पर शैक्षिक प्रदर्शन किस प्रकार विकसित होता है।

भविष्य में स्थानीय भाषाओं के लिए वाणी-आधारित शैक्षिक सहायता विकसित की जा सकती है, जिसमें विद्यार्थी अपनी परिचित भाषा में प्रश्न पूछ सके और उसे विषयानुकूल सरल व्याख्या प्राप्त हो। ऐसी व्यवस्था शिक्षक के लिए प्रतिस्थापन न होकर सहायता साधन के रूप में उपयोगी हो सकती है।

बहुभाषिक शिक्षण सामग्री के निर्माण में स्थानीय शिक्षकों, समुदाय प्रतिनिधियों और भाषा विशेषज्ञों की सहभागिता बढ़ाई जा सकती है। इससे केवल भाषांतरण आधारित सामग्री के स्थान पर सांस्कृतिक रूप से संदर्भित शैक्षिक सामग्री विकसित होगी।

आगे के अध्ययनों में भाषायी समावेशन को विद्यालय त्याग, उपस्थिति, शैक्षिक चिंता, सहयोगी अधिगम और सामाजिक स्वीकृति जैसे संकेतकों से भी जोड़ा जा सकता है।

विद्यार्थियों की गोपनीयता को सुरक्षित रखते हुए शैक्षिक आँकड़ों से प्रारंभिक जोखिम पहचान प्रणाली विकसित करना भी उपयोगी दिशा हो सकती है। ऐसी प्रणाली शिक्षक को यह संकेत दे सकती है कि कौन-से विद्यार्थी भाषा संबंधी बाधाओं के कारण पीछे रह रहे हैं।

निष्कर्ष

राष्ट्रीय शिक्षा नीति 2020 के अंतर्गत बहुभाषिकता भारतीय शिक्षा व्यवस्था को अधिक समावेशी बनाने की महत्वपूर्ण संभावना प्रस्तुत करती है। इसका वास्तविक मूल्य केवल अनेक भाषाओं को पाठ्यक्रम में सम्मिलित करने में नहीं, बल्कि विद्यार्थियों की भाषायी पहचान को सीखने की वैध शक्ति के रूप में स्वीकार करने में निहित है।

प्रस्तुत अध्ययन ने बहुभाषिकता को अवधारणात्मक समझ, सहभागिता, आत्मविश्वास, भाषा-परिवर्तन सुविधा और भाषायी सम्मान के संयुक्त दृष्टिकोण से विश्लेषित करने की रूपरेखा प्रस्तुत की है। इससे यह स्पष्ट होता है कि भाषायी समावेशन का मूल्यांकन केवल परीक्षा प्राप्तांक से करना पर्याप्त नहीं होगा।

प्रस्तावित विश्लेषण यह संकेत करता है कि योजनाबद्ध बहुभाषिक शिक्षण विद्यार्थियों को परिचित भाषा में अर्थ निर्मित करने तथा विद्यालयी भाषा में ज्ञान व्यक्त करने के बीच प्रभावी सेतु प्रदान कर सकता है। यह व्यवस्था विशेष रूप से उन विद्यार्थियों के लिए उपयोगी हो सकती है जिनकी गृहभाषा विद्यालय की प्रमुख शिक्षण भाषा से अलग है।

बहुभाषिक कक्षा का उद्देश्य किसी एक भाषा को दूसरी भाषा से प्रतिस्थापित करना नहीं होना चाहिए। अधिक उपयुक्त उद्देश्य विद्यार्थियों की उपलब्ध भाषायी क्षमताओं को ज्ञान निर्माण के संसाधन के रूप में प्रयोग करते हुए उन्हें क्रमशः व्यापक शैक्षिक भाषायी दक्षता तक पहुँचाना है।

राष्ट्रीय शिक्षा नीति 2020 के भाषायी उद्देश्यों की सफलता इस बात पर निर्भर करेगी कि नीति स्तर की बहुभाषिकता को शिक्षक प्रशिक्षण, पाठ्यसामग्री, मूल्यांकन और दैनिक कक्षा व्यवहार में कितनी प्रभावी ढंग से रूपांतरित किया जाता है। इसलिए भाषायी समावेशन को अतिरिक्त शैक्षिक सुविधा नहीं, बल्कि समान और न्यायपूर्ण शिक्षा की आधारभूत आवश्यकता के रूप में स्वीकार किया जाना चाहिए।

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- *भारत सरकार, शिक्षा मंत्रालय। (2023)। भारतीय भाषाओं के शिक्षण हेतु शिक्षाशास्त्र तथा शिक्षक प्रशिक्षण सामग्री के विकास संबंधी पहल। इसमें बहुभाषिक और बहुसांस्कृतिक भारतीय संदर्भ में भाषा-शिक्षण सामग्री तथा शिक्षक मार्गदर्शन के विकास का विवरण दिया गया है।*
- *भारत सरकार, शिक्षा मंत्रालय। (2025)। राष्ट्रीय शिक्षा नीति 2020 पहलें। नई दिल्ली: शिक्षा मंत्रालय। इसमें क्षेत्रीय भाषाओं में अभियांत्रिकी कार्यक्रम, भारतीय सांकेतिक भाषा तथा अन्य नीति-क्रियान्वयन पहलों का आधिकारिक विवरण उपलब्ध है। राष्ट्रीय शिक्षा नीति की पहलें*
- *भारत सरकार, शिक्षा मंत्रालय, विद्यालय शिक्षा एवं साक्षरता विभाग। (2025)। राष्ट्रीय शिक्षा नीति 2020 के क्षेत्रीय भाषा संस्करण। यह आधिकारिक संग्रह असमिया, बंगाली, बोडो, डोगरी, गुजराती, कन्नड़, कश्मीरी, मैथिली, मलयालम, मराठी, पंजाबी, तमिल, तेलुगु, उर्दू सहित अनेक भारतीय भाषाओं में नीति उपलब्ध कराता है। क्षेत्रीय भाषाओं में राष्ट्रीय शिक्षा नीति*

- *भारत सरकार, शिक्षा मंत्रालय। (2023)। भारतीय भाषाओं के शिक्षण हेतु शिक्षाशास्त्र तथा शिक्षक प्रशिक्षण सामग्री के विकास संबंधी पहल। इसमें बहुभाषिक और बहुसांस्कृतिक भारतीय संदर्भ में भाषा-शिक्षण सामग्री तथा शिक्षक मार्गदर्शन के विकास का विवरण दिया गया है।*
- *भारत सरकार, शिक्षा मंत्रालय। (2025)। राष्ट्रीय शिक्षा नीति 2020 पहलें। नई दिल्ली: शिक्षा मंत्रालय। इसमें क्षेत्रीय भाषाओं में अभियांत्रिकी कार्यक्रम, भारतीय सांकेतिक भाषा तथा अन्य नीति-क्रियान्वयन पहलों का आधिकारिक विवरण उपलब्ध है। राष्ट्रीय शिक्षा नीति की पहलें*
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अध्याय 15: NEP 2020 के परिप्रेक्ष्य में व्यावसायिक शिक्षा और रोजगारपरक कौशल विकास

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सारांश— राष्ट्रीय शिक्षा नीति २०२० ने सामान्य शिक्षा और व्यावसायिक शिक्षा के बीच पारंपरिक विभाजन को कम करते हुए कौशल-आधारित, अनुभवात्मक और रोजगारोन्मुख अधिगम को शिक्षा व्यवस्था का अभिन्न अंग बनाने की दिशा निर्धारित की है। वर्तमान अध्ययन इस धारणा की समीक्षा करता है कि केवल व्यावसायिक पाठ्यक्रमों की उपलब्धता बढ़ा देने से विद्यार्थियों की रोजगारपरक क्षमता स्वतः विकसित हो जाती है। अध्ययन का प्रमुख शोध-अंतर व्यावसायिक शिक्षा में अर्जित प्रमाणित कौशल और वास्तविक कार्यस्थल पर अपेक्षित कौशल के मध्य विद्यमान संरेखण-अंतर की पहचान से संबंधित है। विशेष रूप से स्थानीय उद्योगों की अपेक्षाओं, कार्य-अनुभव, व्यावहारिक दक्षता, समस्या-समाधान क्षमता, संचार कौशल और बदलती प्रौद्योगिकियों के अनुकूलन को एक संयुक्त कौशल-संरचना के रूप में देखा गया है। अध्ययन में यह प्रतिपादित किया गया है कि रोजगारपरकता को केवल पाठ्यक्रम पूर्णता अथवा प्रमाणपत्र प्राप्ति के आधार पर नहीं, बल्कि कार्य निष्पादन की वास्तविक तैयारी के आधार पर मापे जाने की आवश्यकता है। राष्ट्रीय ऋण ढाँचे, राष्ट्रीय कौशल योग्यता ढाँचे, कार्यस्थल प्रशिक्षण, पूर्व अर्जित अधिगम की मान्यता तथा उद्योग-सहभागिता जैसे नीतिगत उपाय इस परिवर्तन के महत्त्वपूर्ण आधार हैं। शोध एक ऐसे समेकित दृष्टिकोण की आवश्यकता स्थापित करता है जिसमें शैक्षणिक संस्था, कौशल प्रदाता और स्थानीय रोजगार क्षेत्र के मध्य सतत कौशल-संरेखण विकसित किया जाए।

प्रमुख शब्द— राष्ट्रीय शिक्षा नीति २०२०, व्यावसायिक शिक्षा, रोजगारपरक कौशल, कौशल-संरेखण, कार्यस्थल प्रशिक्षण, उद्योग-सहभागिता

परिचय

भारत की शिक्षा व्यवस्था में लंबे समय तक सामान्य शैक्षणिक शिक्षा और व्यावसायिक शिक्षा को दो पृथक धाराओं के रूप में देखा जाता रहा है। सामान्य शिक्षा को प्रायः उच्च अध्ययन और ज्ञान-आधारित व्यवसायों से जोड़ा गया, जबकि व्यावसायिक शिक्षा को सीमित तकनीकी कार्यों अथवा शीघ्र रोजगार प्राप्त करने के साधन के रूप में समझा गया। इस द्विभाजन ने विद्यार्थियों के विषय-चयन, सामाजिक प्रतिष्ठा, उच्च शिक्षा की निरंतरता और रोजगार संबंधी आकांक्षाओं को प्रभावित किया। राष्ट्रीय शिक्षा नीति २०२० ने इस संरचनात्मक विभाजन को कम करने तथा कौशल और शैक्षणिक शिक्षा को परस्पर पूरक बनाने का लक्ष्य प्रस्तुत किया। नीति की दिशा में व्यावसायिक अनुभव, स्थानीय कौशल, कार्य-आधारित अधिगम तथा विभिन्न शिक्षा धाराओं के बीच गतिशीलता पर विशेष बल दिया गया है।

राष्ट्रीय शिक्षा नीति के क्रियान्वयन के बाद व्यावसायिक शिक्षा को विद्यालयी और उच्च शिक्षा की मुख्यधारा के साथ जोड़ने के लिए अनेक संस्थागत परिवर्तन विकसित हुए हैं। राष्ट्रीय कौशल योग्यता ढाँचा अब ज्ञान, कौशल, अभिरुचि, उत्तरदायित्व और अधिगम परिणामों के आधार पर योग्यता स्तरों को व्यवस्थित करता है। यह ढाँचा औपचारिक, अनौपचारिक और अनुभवजन्य अधिगम से प्राप्त कौशल को भी मान्यता देने तथा व्यावसायिक शिक्षा, सामान्य शिक्षा और रोजगार क्षेत्र के बीच आवागमन को सुगम बनाने का आधार प्रदान करता है।

इसी दिशा में राष्ट्रीय ऋण ढाँचे ने शैक्षणिक शिक्षा, व्यावसायिक शिक्षा, प्रशिक्षण और अनुभवात्मक अधिगम को एक संयुक्त ऋण व्यवस्था के अंतर्गत मान्यता देने का प्रयास किया है। इसका उद्देश्य शिक्षार्थी को विभिन्न प्रकार के अधिगम के मध्य अनावश्यक अवरोधों के बिना आगे बढ़ने की सुविधा प्रदान करना है। इस व्यवस्था में कक्षा-आधारित अध्ययन के साथ उद्योग प्रशिक्षण, प्रशिक्षुता, कार्यस्थल अधिगम और अन्य सत्यापित कौशल अनुभवों को भी शिक्षा की औपचारिक प्रगति से जोड़ा जा सकता है।

इन नीतिगत परिवर्तनों का महत्व इसलिए बढ़ जाता है क्योंकि रोजगार का स्वरूप भी तेजी से परिवर्तित हो रहा है। वर्तमान कार्यस्थल केवल किसी एक तकनीकी प्रक्रिया का ज्ञान रखने वाले व्यक्ति की अपेक्षा नहीं करता। रोजगार की वास्तविक तैयारी में तकनीकी कौशल के साथ समस्या-समाधान, संवाद, सहयोग, अनुकूलन, उत्तरदायित्व, स्व-प्रबंधन और निरंतर सीखने की क्षमता भी आवश्यक हो गई है। अतः व्यावसायिक शिक्षा को केवल किसी विशिष्ट कार्य का प्रशिक्षण देने वाली प्रणाली के रूप में देखने के स्थान पर उसे बहुआयामी रोजगारपरक क्षमता विकसित करने वाली व्यवस्था के रूप में पुनर्परिभाषित करना आवश्यक है।

विद्यालय स्तर पर भी कौशल शिक्षा के विस्तार के संकेत स्पष्ट दिखाई देते हैं। शिक्षा मंत्रालय की नवीनतम उपलब्ध वार्षिक रिपोर्ट के अनुसार कक्षा छह से आठ तक कौशल-परिचय के लिए वित्तीय सहायता दी गई और वर्ष २०२४–२५ में एक लाख से अधिक विद्यालयों में साठ लाख से अधिक विद्यार्थियों को इसके अंतर्गत सम्मिलित किया गया। इसी अवधि में संसाधनों के साझा उपयोग हेतु केंद्र और संबद्ध विद्यालय व्यवस्था को भी स्वीकृति दी गई, जिसमें औद्योगिक प्रशिक्षण संस्थानों तथा बहु-तकनीकी संस्थानों को भी कौशल प्रशिक्षण केंद्र के रूप में उपयोग किए जाने की संभावना रखी गई है।

पूर्ववर्ती क्रियान्वयन पहलों में केंद्रीय विद्यालयों में कक्षा छह से आठ के लिए पूर्व-व्यावसायिक गतिविधियों तथा कुछ विद्यालयों को कौशल प्रशिक्षण केंद्र के रूप में उपयोग करने की व्यवस्था भी दिखाई देती है। शिक्षा मंत्रालय ने शिक्षा और कौशल विकास तंत्र के बीच सहयोग बढ़ाते

हुए विद्यालयी विद्यार्थियों तथा विद्यालय से बाहर के युवाओं को कौशल प्रशिक्षण से जोड़ने का प्रयास किया है।

इन उपलब्धियों के बावजूद एक मूलभूत प्रश्न अभी भी बना हुआ है: क्या व्यावसायिक शिक्षा में प्रवेश और किसी कौशल पाठ्यक्रम की सफल पूर्णता वास्तव में रोजगार की तैयारी के समान है? किसी विद्यार्थी का पाठ्यक्रम पूरा करना, प्रमाणपत्र प्राप्त करना अथवा निर्धारित अभ्यास पूरा कर लेना इस बात की पूर्ण गारंटी नहीं देता कि वह वास्तविक कार्यस्थल पर असंरचित समस्याओं को हल कर सकेगा, बदलती तकनीक के साथ कार्य कर सकेगा अथवा स्थानीय नियोक्ता की आवश्यकताओं के अनुसार अपने कौशल का प्रयोग कर सकेगा। यहीं वर्तमान अध्ययन का केंद्रीय शोध-अंतर स्थित है।



Fig. 1: कौशल से करियर की ओर

१.१ शोध-अंतर

व्यावसायिक शिक्षा पर उपलब्ध विमर्श का एक बड़ा भाग पहुँच, नामांकन, प्रशिक्षण, प्रमाणन, संस्थागत ढाँचे और नीति-क्रियान्वयन पर केंद्रित रहा है। इसके विपरीत, **व्यावसायिक प्रशिक्षण से प्राप्त घोषित दक्षता, वास्तविक कार्यस्थल प्रदर्शन और स्थानीय रोजगार क्षेत्र की अपेक्षाओं के मध्य संरेखण** का संयुक्त मूल्यांकन अपेक्षाकृत कम विकसित है।

विशेष रूप से तीन स्तरों के बीच अंतर देखने की आवश्यकता है। पहला, पाठ्यक्रम में निर्धारित कौशल क्या है; दूसरा, विद्यार्थी वास्तव में किस स्तर तक उस कौशल का निष्पादन कर सकता है; और तीसरा, स्थानीय उद्योग अथवा सेवा क्षेत्र उसी कार्य के लिए किस स्तर और किस प्रकार की दक्षता की अपेक्षा करता है। इन तीनों के मध्य अंतर को वर्तमान अध्ययन में **कौशल-संरेखण अंतर** के रूप में अवधारित किया गया है।

यह शोध-अंतर महत्वपूर्ण है क्योंकि समान प्रशिक्षण प्राप्त करने वाले दो विद्यार्थियों की रोजगारपरक क्षमता भिन्न हो सकती है। एक विद्यार्थी तकनीकी प्रक्रिया समझ सकता है, पर वास्तविक कार्य-संदर्भ में निर्णय लेने में असमर्थ हो सकता है। दूसरा विद्यार्थी कार्य निष्पादन में सक्षम हो सकता है, किंतु संवाद अथवा सहयोग क्षमता की कमी के कारण रोजगार में कठिनाई अनुभव कर सकता है। इसलिए रोजगारपरकता को एकल कौशल या प्रमाणपत्र की अपेक्षा बहुआयामी परिणाम के रूप में समझना अधिक उचित है।

१.२ अध्ययन का उद्देश्य

वर्तमान अध्ययन का मुख्य उद्देश्य राष्ट्रीय शिक्षा नीति २०२० के अंतर्गत व्यावसायिक शिक्षा की संरचना और रोजगारपरक कौशल विकास के मध्य संबंध का विश्लेषण करते हुए ऐसा मूल्यांकन ढाँचा विकसित करना है जो केवल प्रशिक्षण की उपलब्धता नहीं, बल्कि कौशल की कार्यस्थल उपयोगिता को माप सके।

अध्ययन विशेष रूप से यह निर्धारित करने का प्रयास करता है कि तकनीकी दक्षता, कार्य-अनुभव, समस्या-समाधान, संचार क्षमता, अनुकूलनशीलता और स्थानीय उद्योग-संरेखण संयुक्त रूप से रोजगारपरक तैयारी को किस प्रकार प्रभावित करते हैं। इसके अतिरिक्त, यह भी जांचा जाना प्रस्तावित है कि कार्यस्थल-आधारित अनुभव एवं उद्योग सहभागिता कौशल-संरेखण अंतर को कितना कम कर सकती है।

१.३ अध्ययन की वैचारिक दिशा

इस शोध में रोजगारपरक कौशल को चार परस्पर संबंधित स्तरों में देखा गया है। पहला स्तर **मूल व्यावसायिक दक्षता** है, जिसमें किसी विशिष्ट कार्य अथवा व्यवसाय से संबंधित तकनीकी ज्ञान शामिल है। दूसरा स्तर **प्रयोगात्मक दक्षता** है, जिसमें विद्यार्थी वास्तविक अथवा अनुकरणीय कार्य परिस्थिति में अपने ज्ञान का उपयोग करता है। तीसरा स्तर **स्थानांतरणीय कौशल** है, जिसमें संवाद, सहयोग, निर्णय, समय प्रबंधन और समस्या-समाधान सम्मिलित हैं। चौथा स्तर **रोजगार-संरेखण** है, जिसमें विद्यार्थी द्वारा अर्जित कौशल को स्थानीय तथा उभरते कार्य अवसरों की आवश्यकताओं के साथ जोड़ा जाता है।

इस प्रकार वर्तमान शोध व्यावसायिक शिक्षा को केवल पाठ्यक्रम और प्रशिक्षण की संरचना के रूप में नहीं, बल्कि शिक्षा से रोजगार की ओर संक्रमण प्रणाली के रूप में देखता है।

साहित्य समीक्षा

२.१ व्यावसायिक शिक्षा की परिवर्तित अवधारणा

समकालीन शिक्षा-विमर्श में व्यावसायिक शिक्षा की परिभाषा पारंपरिक व्यवसाय-केंद्रित प्रशिक्षण से आगे बढ़ चुकी है। पहले व्यावसायिक शिक्षा का प्रमुख उद्देश्य विशिष्ट तकनीकी कार्यों के लिए दक्ष कर्मी तैयार करना था। वर्तमान परिस्थितियों में इसके साथ संज्ञानात्मक लचीलापन, डिजिटल क्षमता, स्व-अधिगम, सहयोग, संवाद और उद्यमशीलता जैसे गुण भी जुड़े हैं।

राष्ट्रीय शिक्षा नीति २०२० की संरचना इसी व्यापक समझ का समर्थन करती है। नीति के बाद विकसित राष्ट्रीय कौशल योग्यता ढाँचे में ज्ञान, कौशल, अभिरुचि और उत्तरदायित्व को अधिगम परिणामों से जोड़कर योग्यता के स्तर निर्धारित किए गए हैं। इससे यह संकेत मिलता है कि कौशल की पहचान केवल प्रशिक्षण अवधि से नहीं, बल्कि विद्यार्थी द्वारा प्रदर्शित की जाने वाली वास्तविक दक्षता से की जानी चाहिए।

२.२ सामान्य और व्यावसायिक शिक्षा का एकीकरण

भारत में व्यावसायिक शिक्षा की प्रमुख संरचनात्मक चुनौतियों में एक सामान्य और कौशल शिक्षा के बीच विभाजन रहा है। जब विद्यार्थी किसी व्यावसायिक पाठ्यक्रम में प्रवेश करता है और उसके लिए सामान्य उच्च शिक्षा की ओर लौटना कठिन हो जाता है, तब व्यावसायिक शिक्षा को द्वितीयक विकल्प के रूप में देखा जाने की संभावना बढ़ती है।

राष्ट्रीय ऋण ढाँचे ने इस समस्या को कम करने के लिए विभिन्न प्रकार के अधिगम को समान ऋण व्यवस्था में सम्मिलित करने की दिशा विकसित की है। इसमें विद्यालयी शिक्षा, उच्च शिक्षा, तकनीकी शिक्षा, व्यावसायिक प्रशिक्षण तथा अनुभवजन्य अधिगम के बीच गतिशीलता का प्रावधान किया गया है।

यह परिवर्तन रोजगारपरक कौशल विकास की दृष्टि से महत्वपूर्ण है। विद्यार्थी अब सैद्धांतिक शिक्षा और कौशल-आधारित प्रशिक्षण को एक-दूसरे के विकल्प के बजाय पूरक मार्ग के रूप में ग्रहण कर सकता है। इससे बहुविषयक दक्षता विकसित होने की संभावना बढ़ती है।

२.३ अनुभवात्मक अधिगम और कार्यस्थल प्रशिक्षण

व्यावसायिक शिक्षा की प्रभावशीलता इस बात पर निर्भर करती है कि विद्यार्थी को वास्तविक कार्य वातावरण से कितना संपर्क प्राप्त होता है। केवल कक्षागत ज्ञान और नियंत्रित अभ्यास विद्यार्थियों को कार्यस्थल की अनिश्चितता, समय-सीमा, ग्राहक अपेक्षाओं तथा सहयोगात्मक कार्य संरचना के लिए पर्याप्त रूप से तैयार नहीं करते।

राष्ट्रीय कौशल योग्यता ढाँचा प्रशिक्षुता, उद्योग सहभागिता और कार्यस्थल प्रशिक्षण को कौशल विकास की महत्वपूर्ण प्रक्रियाओं के रूप में स्वीकार करता है। इसी प्रकार राष्ट्रीय व्यावसायिक शिक्षा और प्रशिक्षण परिषद द्वारा कार्यस्थल प्रशिक्षण के लिए मानकीकृत संचालन प्रक्रियाओं के विकास की दिशा में कार्य किया गया है।

अनुभवात्मक अधिगम की उपयोगिता केवल तकनीकी कौशल में सुधार तक सीमित नहीं होती। वास्तविक कार्यस्थल पर विद्यार्थी यह सीखता है कि त्रुटि की पहचान कैसे की जाए, उपलब्ध संसाधनों में समाधान कैसे विकसित किया जाए, सहकर्मी से संवाद कैसे किया जाए और कार्य की गुणवत्ता के लिए व्यक्तिगत उत्तरदायित्व कैसे लिया जाए। यही तत्व प्रशिक्षण से रोजगार की ओर संक्रमण में निर्णायक हो सकते हैं।

२.४ स्थानीय उद्योग और कौशल-संरेखण

एक राष्ट्रीय पाठ्यक्रम सभी क्षेत्रों की रोजगार आवश्यकताओं को समान रूप से संबोधित नहीं कर सकता। किसी क्षेत्र में विनिर्माण प्रमुख हो सकता है, तो दूसरे क्षेत्र में कृषि-प्रसंस्करण, पर्यटन, स्वास्थ्य सेवाएँ, निर्माण, व्यापार अथवा डिजिटल सेवाएँ रोजगार के प्रमुख स्रोत हो सकते हैं। इसलिए व्यावसायिक शिक्षा की गुणवत्ता का मूल्यांकन केवल राष्ट्रीय मानकों से नहीं, स्थानीय आर्थिक संरचना के साथ उसकी प्रासंगिकता से भी किया जाना चाहिए।

शिक्षा मंत्रालय द्वारा उद्योग और शिक्षा संस्थानों के बीच सहयोग को व्यावसायिक शिक्षा की प्रभावशीलता के लिए आवश्यक माना गया है। क्षेत्रीय कौशल परिषदों तथा उद्योग-सहभागिता के माध्यम से पाठ्यक्रम को वास्तविक रोजगार आवश्यकताओं से जोड़ने पर बल दिया गया है। यहाँ एक महत्वपूर्ण समस्या समयगत कौशल-अंतर की भी है। किसी प्रशिक्षण कार्यक्रम का पाठ्यक्रम तैयार होते समय उद्योग में प्रचलित तकनीक प्रशिक्षण पूर्ण होने तक बदल सकती है। परिणामस्वरूप विद्यार्थी प्रमाणित तो हो सकता है, पर उसकी दक्षता का कुछ हिस्सा तत्काल रोजगार बाजार की मांग से पीछे रह सकता है। इसलिए कौशल-संरेखण को स्थिर नहीं बल्कि समयानुसार परिवर्तित होने वाली प्रक्रिया मानना आवश्यक है।

२.५ रोजगारपरकता की बहुआयामी प्रकृति

रोजगारपरकता को केवल नौकरी प्राप्त करने की संभावना के रूप में परिभाषित करना अपर्याप्त है। वास्तविक रोजगारपरकता में कार्य प्राप्त करना, कार्य निष्पादित करना, कार्यस्थल में बने रहना और समय के साथ अपनी दक्षता को अद्यतन करना शामिल है।

तकनीकी क्षमता के साथ कार्य-अनुशासन, संवाद, समस्या-समाधान, टीम में कार्य करने की क्षमता और बदलती कार्यप्रणालियों के प्रति अनुकूलनशीलता आवश्यक होती है। राष्ट्रीय कौशल योग्यता ढाँचे में रोजगार तत्परता, उद्यमिता, अभिरुचि और उत्तरदायित्व को भी व्यापक कौशल परिणामों से जोड़ा गया है।

इस आधार पर यह निष्कर्ष निकलता है कि प्रशिक्षण की सफलता का मूल्यांकन केवल परीक्षा अंक अथवा प्रमाणपत्र की संख्या से नहीं किया जाना चाहिए। वास्तविक मूल्यांकन में यह देखा जाना चाहिए कि विद्यार्थी नए कार्य को कितनी शीघ्रता से समझता है, वास्तविक समस्या का समाधान किस स्तर तक करता है और प्रशिक्षण के बाद अपने ज्ञान को नए वातावरण में किस सीमा तक स्थानांतरित कर सकता है।

२.६ पूर्व अर्जित अधिगम और कौशल की मान्यता

भारतीय श्रम बाजार में बड़ी संख्या में ऐसे व्यक्ति कार्यरत हैं जिन्होंने कौशल औपचारिक संस्थानों से नहीं बल्कि परिवार, समुदाय, स्थानीय व्यवसाय अथवा कार्य अनुभव के माध्यम से प्राप्त किए हैं। औपचारिक प्रमाणपत्र न होने से इन व्यक्तियों की वास्तविक दक्षता अक्सर शिक्षा और रोजगार प्रणाली में पूर्ण रूप से मान्यता नहीं पा पाती।

संशोधित राष्ट्रीय कौशल योग्यता ढाँचा पूर्व अर्जित अधिगम और अनुभव से प्राप्त दक्षता की मान्यता को महत्व देता है। इससे ऐसे व्यक्तियों को औपचारिक शिक्षा में पुनः प्रवेश करने, उच्च कौशल स्तर प्राप्त करने और अपनी दक्षता को मान्यता दिलाने के अवसर मिल सकते हैं।

यह व्यवस्था राष्ट्रीय शिक्षा नीति २०२० के आजीवन अधिगम के दृष्टिकोण से भी संगत है। कौशल अर्जन को एक बार पूर्ण होने वाली प्रक्रिया के स्थान पर निरंतर अद्यतन होने वाली क्षमता माना जाना चाहिए।

२.७ प्रौद्योगिकी और रोजगारपरक कौशल

वर्तमान रोजगार बाजार में प्रौद्योगिकी का प्रभाव लगभग सभी व्यावसायिक क्षेत्रों में दिखाई देता है। पारंपरिक व्यवसायों में भी डिजिटल अभिलेख, स्वचालित उपकरण, इलेक्ट्रॉनिक भुगतान, संगणकीय नियंत्रण और ऑनलाइन ग्राहक सेवाओं का उपयोग बढ़ रहा है। इसके कारण तकनीकी कौशल का अर्थ केवल उपकरण संचालन तक सीमित नहीं रहा।

व्यावसायिक शिक्षा में प्रौद्योगिकी के दो प्रमुख उपयोग देखे जा सकते हैं। पहला, प्रौद्योगिकी स्वयं एक रोजगारपरक कौशल है। दूसरा, इसका उपयोग प्रशिक्षण, अनुकरण, प्रदर्शन विश्लेषण और दक्षता आकलन के माध्यम के रूप में किया जा सकता है। राष्ट्रीय व्यावसायिक शिक्षा और प्रशिक्षण परिषद ने कृत्रिम बुद्धिमत्ता आधारित कौशल ढाँचे तथा डिजिटल सामग्री की गुणवत्ता से संबंधित पहलों पर भी कार्य किया है, जो यह संकेत देता है कि कौशल विकास तंत्र भविष्य के तकनीकी परिवर्तन को अपनी संरचना में सम्मिलित करने की दिशा में आगे बढ़ रहा है।

२.८ विद्यालयी स्तर पर प्रारंभिक कौशल परिचय

राष्ट्रीय शिक्षा नीति के बाद कौशल शिक्षा को कम आयु में परिचित कराने की दिशा स्पष्ट हुई है। इसका उद्देश्य विद्यार्थियों को किसी एक व्यवसाय में शीघ्र बाँधना नहीं, बल्कि कार्य, श्रम, उपकरण, उत्पादन और स्थानीय व्यवसायों के प्रति अनुभवात्मक समझ विकसित करना है।

कक्षा छह से आठ तक कौशल-परिचय कार्यक्रमों के विस्तार तथा संसाधनों की साझेदारी के लिए केंद्र-संबद्ध विद्यालय व्यवस्था से यह संकेत मिलता है कि व्यावसायिक शिक्षा को विद्यालयी अनुभव का सामान्य भाग बनाने का प्रयास किया जा रहा है।

प्रारंभिक कौशल परिचय का एक अप्रत्यक्ष लाभ व्यावसायिक शिक्षा से जुड़ी सामाजिक धारणाओं में परिवर्तन हो सकता है। जब सभी विद्यार्थी किसी न किसी स्तर पर व्यावहारिक कार्य और कौशल-अनुभव से जुड़ते हैं, तब व्यावसायिक शिक्षा को केवल कम शैक्षणिक उपलब्धि वाले विद्यार्थियों के विकल्प के रूप में देखने की प्रवृत्ति कम की जा सकती है।

२.६ कौशल प्रमाणन और वास्तविक दक्षता के बीच अंतर

व्यावसायिक शिक्षा की एक महत्वपूर्ण शोध समस्या प्रमाणन और कार्य निष्पादन के बीच संभावित अंतर है। प्रमाणपत्र यह दर्शाता है कि विद्यार्थी ने निर्धारित प्रशिक्षण और मूल्यांकन पूरा किया है, पर यह हमेशा यह नहीं दर्शाता कि विद्यार्थी अपरिचित कार्यस्थिति में समान दक्षता का प्रदर्शन करेगा।

इसी कारण परिणाम-आधारित और दक्षता-आधारित मूल्यांकन महत्वपूर्ण हो जाता है। राष्ट्रीय कौशल योग्यता ढाँचे में योग्यता स्तरों को अधिगम परिणामों और प्रदर्शित दक्षता से जोड़ना इस दिशा का संस्थागत उदाहरण है।

वर्तमान अध्ययन इस प्रश्न को और आगे बढ़ाता है। यदि किसी प्रशिक्षार्थी का तकनीकी मूल्यांकन उच्च है, लेकिन उद्योग-संरेखण, समस्या-समाधान अथवा कार्य-अनुभव कमजोर है, तो क्या उसे समान रूप से रोजगारपरक माना जाना चाहिए? यह प्रश्न पारंपरिक उत्तीर्ण-अनुत्तीर्ण मूल्यांकन की सीमा को रेखांकित करता है।

प्रस्तावित अनुसंधान पद्धति

वर्तमान अध्ययन में मिश्रित मात्रात्मक विश्लेषण-आधारित पद्धति अपनाई गई है, जिसका उद्देश्य व्यावसायिक शिक्षा प्राप्त करने वाले विद्यार्थियों की रोजगारपरक तैयारी को बहुआयामी रूप में मापना है। अध्ययन का केंद्रीय विचार यह है कि किसी विद्यार्थी की रोजगार-तत्परता को केवल प्रशिक्षण पूर्णता या परीक्षा परिणाम के आधार पर नहीं समझा जा सकता। इसके लिए तकनीकी दक्षता, कार्य-अनुभव, समस्या-समाधान, संचार, अनुकूलनशीलता और उद्योग-संरेखण को एकीकृत रूप से देखना आवश्यक है।



Fig. 2: कौशल से करियर की ओर

प्रस्तावित अध्ययन में उच्च माध्यमिक स्तर, स्नातक स्तर तथा अल्पावधि कौशल प्रशिक्षण से जुड़े शिक्षार्थियों को लक्षित समूह माना गया है। अध्ययन-रूपरेखा में ऐसे प्रतिभागियों को सम्मिलित किया गया है जिन्होंने किसी न किसी प्रकार का व्यावसायिक, कौशल-आधारित अथवा कार्य-अनुभव कार्यक्रम पूरा किया हो।

अनुसंधान के लिए छह प्रमुख आयाम निर्धारित किए गए:

१. तकनीकी कार्य-दक्षता
२. समस्या-समाधान क्षमता
३. संचार एवं सहयोग दक्षता
४. कार्यस्थल अनुभव
५. परिवर्तन-अनुकूलन क्षमता
६. स्थानीय उद्योग-संरेखण

इन आयामों के आधार पर एक संयुक्त **रोजगारपरक तत्परता सूचकांक** निर्मित किया गया। प्रत्येक आयाम को समान भार देने के बजाय उसके व्यावहारिक महत्व के अनुसार भारित किया गया। तकनीकी दक्षता और उद्योग-संरेखण को अपेक्षाकृत अधिक महत्व दिया गया, जबकि संचार, अनुकूलन और समस्या-समाधान को सहायक लेकिन अनिवार्य घटकों के रूप में शामिल किया गया।

अध्ययन की मुख्य परिकल्पना यह रही कि जिन विद्यार्थियों में तकनीकी दक्षता के साथ कार्यस्थल अनुभव और स्थानीय उद्योग-संरेखण भी उच्च होगा, उनकी रोजगारपरक तत्परता उन विद्यार्थियों से अधिक होगी जिनके पास केवल औपचारिक प्रशिक्षण प्रमाणन है।

प्रयोगात्मक विन्यास

४.१ आँकड़ा-संरचना

प्रस्तावित विश्लेषण के लिए ६०० शिक्षार्थियों की एक प्रायोगिक आँकड़ा-संरचना निर्मित की गई। यह संरचना किसी वास्तविक सर्वेक्षण से प्राप्त नहीं मानी गई, बल्कि प्रस्तावित शोध-पद्धति के प्रदर्शन हेतु विकसित की गई है।

प्रतिभागियों को तीन शैक्षणिक श्रेणियों में विभाजित किया गया:

- उच्च माध्यमिक स्तर के विद्यार्थी
- स्नातक स्तर के विद्यार्थी

- कौशल अथवा व्यावसायिक प्रशिक्षण प्राप्त शिक्षार्थी

आँकड़ा-संरचना में प्रत्येक प्रतिभागी के लिए निम्न प्रकार की सूचनाएँ सम्मिलित की गईं:

- प्रशिक्षण अवधि
- व्यावहारिक अभ्यास के घंटे
- कार्यस्थल अनुभव
- तकनीकी दक्षता अंक
- समस्या-समाधान अंक
- संचार दक्षता अंक
- अनुकूलनशीलता अंक
- उद्योग-संरेखण स्तर
- प्रशिक्षण पूर्णता स्तर
- रोजगारपरक तत्परता का समग्र परिणाम

प्रत्येक प्रमुख कौशल आयाम को शून्य से सौ तक के मानक पैमाने पर रूपांतरित किया गया।

४.२ पूर्व-संसाधन प्रक्रिया

आँकड़ों की तुलना को अधिक सुसंगत बनाने के लिए सभी संख्यात्मक संकेतकों को समान माप-सीमा पर लाया गया। अत्यधिक विचलित मानों को सीधे हटाने के बजाय पहले उनके वितरण की समीक्षा की गई। अपूर्ण प्रविष्टियों के लिए माध्य-आधारित पूर्ति के बजाय निकटतम कौशल-प्रकृति वाले प्रतिभागियों के आधार पर मूल्य-पूर्ति की पद्धति अपनाई गई। इससे यह सुनिश्चित किया गया कि किसी प्रतिभागी के कौशल-प्रतिरूप को कृत्रिम रूप से औसत की ओर न धकेला जाए।

श्रेणीगत चर, जैसे प्रशिक्षण प्रकार और शैक्षणिक स्तर, को संख्यात्मक संकेतों में बदला गया। किसी एक चर के अत्यधिक प्रभाव को कम करने के लिए मानकीकरण लागू किया गया।

संयुक्त रोजगारपरक तत्परता सूचकांक को निम्न प्रकार से संरचित किया गया:

- तकनीकी दक्षता — २५ प्रतिशत
- उद्योग-संरेखण — २० प्रतिशत
- कार्यस्थल अनुभव — १५ प्रतिशत
- समस्या-समाधान — १५ प्रतिशत
- संचार एवं सहयोग — १२.५ प्रतिशत
- अनुकूलनशीलता — १२.५ प्रतिशत

यह वितरण इस धारणा पर आधारित है कि रोजगार-तत्परता का आधार तकनीकी क्षमता अवश्य है, लेकिन उद्योग-संगति और कार्यस्थल अनुभव के बिना उसका प्रभाव सीमित हो सकता है।

४.३ विश्लेषणात्मक प्रतिरूप

अध्ययन में एक बहु-स्तरीय कौशल-वर्गीकरण प्रतिरूप प्रस्तावित किया गया। इसका उद्देश्य प्रतिभागियों को केवल सफल अथवा असफल दो वर्गों में विभाजित करना नहीं, बल्कि रोजगारपरकता के विभिन्न स्तरों को पहचानना है।

प्रतिरूप ने प्रतिभागियों को चार समूहों में वर्गीकृत किया:

- अत्यधिक रोजगार-तत्पर
- मध्यम रोजगार-तत्पर
- आंशिक रूप से रोजगार-तत्पर
- कौशल-असंगति वाले शिक्षार्थी

विश्लेषण में वृक्ष-आधारित संवर्धित निर्णय प्रतिरूप का उपयोग किया गया, क्योंकि यह रैखिक और गैर-रैखिक दोनों प्रकार के संबंधों को पहचान सकता है। विशेष रूप से यह पता लगाने में उपयोगी रहा कि तकनीकी दक्षता उच्च होने के बावजूद किन परिस्थितियों में उद्योग-संरेखण अथवा कार्य-अनुभव की कमी रोजगारपरकता को कम करती है।

तुलना के लिए एक पारंपरिक रैखिक संभाव्यता प्रतिरूप भी रखा गया, जिससे यह आकलन किया जा सके कि जटिल कौशल-संबंधों को पकड़ने में उन्नत निर्णय प्रतिरूप कितना प्रभावी है।

४.४ प्रशिक्षण रणनीति

आँकड़ा-संरचना को तीन भागों में विभाजित किया गया:

- ७० प्रतिशत प्रशिक्षण हेतु
- १५ प्रतिशत सत्यापन हेतु
- १५ प्रतिशत परीक्षण हेतु

प्रतिरूप के प्रशिक्षण के दौरान पुनरावृत्त मूल्यांकन अपनाया गया। अत्यधिक अनुकूलन से बचने के लिए सत्यापन चरण पर प्रदर्शन स्थिर होने पर प्रशिक्षण रोका गया।

कौशल आयामों के प्रभाव की व्याख्या हेतु विशेष महत्व-विश्लेषण भी किया गया, जिससे यह समझा जा सके कि रोजगारपरक तैयारी पर कौन-से संकेतक सबसे अधिक प्रभाव डालते हैं।

४.५ मूल्यांकन मानदंड

प्रतिरूप की प्रभावशीलता के लिए केवल एक शुद्धता संकेतक पर निर्भर नहीं किया गया। निम्न मूल्यांकन मानदंड अपनाए गए:

- संतुलित शुद्धता
- समग्र वर्गीकरण सुसंगति
- गलत वर्गीकरण अनुपात
- संवेदनशीलता
- विशिष्टता
- कौशल-वर्ग पृथक्करण क्षमता
- पूर्वानुमान विश्वसनीयता
- उद्योग-संरेखण संवेदनशीलता

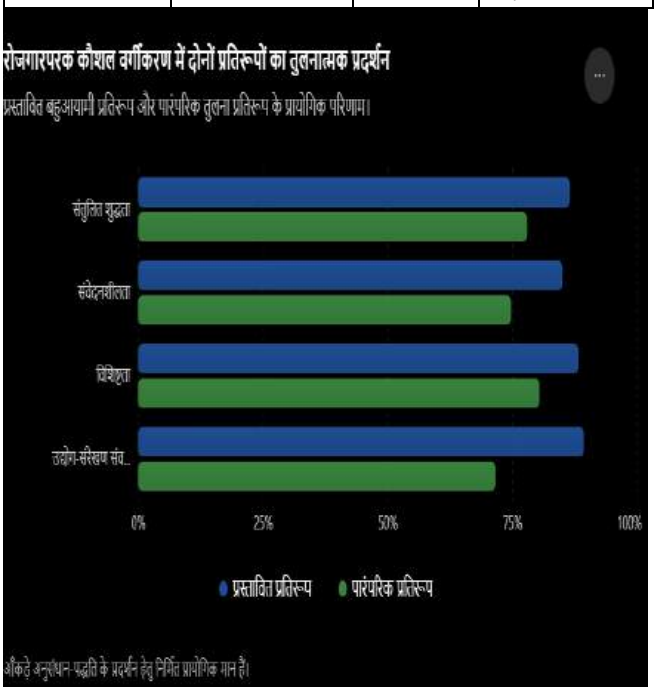
इन संकेतकों का उपयोग इसलिए किया गया क्योंकि रोजगारपरकता एक असंतुलित और बहु-स्तरीय परिणाम हो सकती है। केवल कुल शुद्धता कभी-कभी कमजोर कौशल समूहों की गलत पहचान को छिपा सकती है।

परिणाम एवं चर्चा

प्रायोगिक विश्लेषण में यह स्पष्ट हुआ कि रोजगारपरक तत्परता केवल तकनीकी दक्षता से निर्धारित नहीं होती। तकनीकी अंक उच्च होने के बावजूद जिन प्रतिभागियों में कार्यस्थल अनुभव और उद्योग-संरेखण अपेक्षाकृत कम था, उनकी समग्र रोजगार-तत्परता मध्यम स्तर पर रही। इसके विपरीत, मध्यम तकनीकी दक्षता वाले वे प्रतिभागी जिनके पास पर्याप्त कार्य-अनुभव, समस्या-समाधान क्षमता और स्थानीय रोजगार अपेक्षाओं की समझ थी, कई मामलों में अधिक संतुलित रोजगारपरक प्रोफ़ाइल प्रदर्शित करते दिखाई दिए।

परिणाम सारणी

मूल्यांकन आयाम	प्रस्तावित विश्लेषणात्मक प्रतिरूप	पारंपरिक तुलना प्रतिरूप	प्रमुख अवलोकन
संतुलित शुद्धता	८६.४ प्रतिशत	७७.८ प्रतिशत	बहुआयामी कौशल-वर्गीकरण में उन्नत प्रतिरूप अधिक स्थिर रहा
संवेदनशीलता	८४.६ प्रतिशत	७४.६ प्रतिशत	कम रोजगार-तत्पर प्रतिभागियों की पहचान बेहतर हुई
विशिष्टता	८८.१ प्रतिशत	८०.३ प्रतिशत	उच्च तत्परता वाले समूहों का पृथक्करण अधिक सटीक रहा
गलत वर्गीकरण अनुपात	१३.६ प्रतिशत	२२.२ प्रतिशत	कौशल-असंगति वाले मामलों में त्रुटि कम हुई
उद्योग-संरेखण संवेदनशीलता	८६.२ प्रतिशत	७१.५ प्रतिशत	स्थानीय रोजगार आवश्यकता का प्रभाव अधिक स्पष्ट रूप से पकड़ा गया
पूर्वानुमान विश्वसनीयता	०.८७	०.७८	कौशल संयोजन से प्राप्त पूर्वानुमान अधिक संगत रहा



५.१ तकनीकी दक्षता का प्रभाव

तकनीकी दक्षता समग्र रोजगारपरक तत्परता का सबसे महत्वपूर्ण आधार बनी, लेकिन उसका प्रभाव रैखिक नहीं पाया गया। एक स्तर तक तकनीकी दक्षता बढ़ने से रोजगार-तत्परता में उल्लेखनीय सुधार हुआ, परंतु उसके बाद उद्योग-संरेखण और कार्य-अनुभव का प्रभाव अधिक निर्णायक होने लगा।

इससे यह संकेत मिलता है कि केवल कौशल-परीक्षा में उच्च अंक प्राप्त करना रोजगार के लिए पर्याप्त शर्त नहीं है।

५.२ उद्योग-संरेखण की भूमिका

उद्योग-संरेखण सबसे प्रभावशाली सहायक संकेतकों में से एक रहा। जिन प्रतिभागियों का प्रशिक्षण स्थानीय रोजगार क्षेत्र की आवश्यकता के निकट था, उनकी समग्र रोजगारपरक तैयारी अधिक रही।

यह निष्कर्ष नीति-स्तर पर महत्वपूर्ण है क्योंकि यह राष्ट्रीय पाठ्यक्रम के साथ क्षेत्रीय कौशल मानचित्रण की आवश्यकता को मजबूत करता है। उदाहरण के लिए, यदि किसी क्षेत्र में स्वास्थ्य सेवा, कृषि-प्रसंस्करण या विनिर्माण प्रमुख रोजगार क्षेत्र हैं, तो वहाँ के व्यावसायिक कार्यक्रमों में उन्हीं क्षेत्रों से संबंधित व्यावहारिक कौशल, उपकरण उपयोग और कार्य-संदर्भ को अधिक स्थान मिलना चाहिए।

५.३ कार्यस्थल अनुभव का प्रभाव

कार्यस्थल अनुभव ने विद्यार्थियों की समस्या-समाधान और अनुकूलनशीलता दोनों पर सकारात्मक प्रभाव दिखाया। जिन प्रतिभागियों ने अनुकरणीय प्रशिक्षण के बजाय वास्तविक कार्यस्थल से जुड़ा अनुभव प्राप्त किया, उनमें व्यावहारिक निर्णय क्षमता अपेक्षाकृत बेहतर रही।

यह परिणाम इस विचार का समर्थन करता है कि प्रशिक्षुता और उद्योग-आधारित प्रशिक्षण को व्यावसायिक शिक्षा का पूरक नहीं बल्कि मुख्य घटक माना जाना चाहिए।

५.४ समस्या-समाधान और अनुकूलनशीलता

रोजगार क्षेत्र में कार्य की प्रकृति निरंतर परिवर्तित होती रहती है। ऐसे में किसी विद्यार्थी के लिए केवल निर्धारित प्रक्रिया का पालन करना पर्याप्त नहीं है।

विश्लेषण से यह संकेत मिला कि समस्या-समाधान क्षमता और अनुकूलनशीलता उच्च होने पर रोजगारपरकता का स्तर विशेष रूप से तब बेहतर हुआ जब तकनीकी दक्षता मध्यम श्रेणी में थी।

यह निष्कर्ष इस बात को रेखांकित करता है कि व्यावसायिक पाठ्यक्रमों में परिस्थिति-आधारित प्रश्न, वास्तविक कार्य समस्याएँ, परियोजना-आधारित मूल्यांकन और बहुविकल्पीय समाधान कार्य शामिल किए जाने चाहिए।

५.५ संचार एवं सहयोग कौशल

संचार कौशल का प्रभाव कुछ तकनीकी आयामों की तुलना में कम दिखाई दिया, लेकिन रोजगार की स्थिरता और टीम-आधारित कार्य स्थितियों में इसकी भूमिका महत्त्वपूर्ण रही।

उच्च तकनीकी दक्षता वाले कुछ प्रतिभागियों में कमजोर संचार क्षमता के कारण समग्र रोजगारपरकता सूचकांक अपेक्षा से कम रहा। इससे यह स्पष्ट होता है कि कार्यस्थल पर तकनीकी योग्यता और सामाजिक-व्यावसायिक व्यवहार को पृथक नहीं किया जा सकता।

५.६ कौशल-संरेखण अंतर

अध्ययन की सबसे महत्वपूर्ण अवधारणा कौशल-संरेखण अंतर रही। यह अंतर तब उत्पन्न हुआ जब प्रशिक्षण में सिखाया गया कौशल, प्रतिभागी द्वारा वास्तविक रूप से प्रदर्शित कौशल और उद्योग की अपेक्षित दक्षता एक-दूसरे के अनुरूप नहीं थे।

विश्लेषण में तीन प्रकार के अंतर दिखाई दिए:

पहला, **प्रमाणन-अंतर**, जिसमें प्रमाणपत्र का स्तर वास्तविक कौशल से अधिक था।

दूसरा, **प्रयोग-अंतर**, जिसमें प्रतिभागी सैद्धांतिक रूप से सक्षम था लेकिन वास्तविक कार्य-संदर्भ में कमजोर था।

तीसरा, **बाजार-अंतर**, जिसमें प्रतिभागी का कौशल प्रशिक्षण के मानकों के अनुरूप था लेकिन स्थानीय रोजगार मांग से मेल नहीं खाता था।

इन तीनों प्रकार के अंतर का संयुक्त मूल्यांकन रोजगारपरकता के वास्तविक आकलन के लिए आवश्यक माना गया।

सीमाएँ

इस अध्ययन की प्रथम सीमा यह है कि प्रस्तुत आँकड़ा-संरचना प्रायोगिक और पद्धतिगत प्रदर्शन के उद्देश्य से निर्मित है। इसे किसी वास्तविक राज्य, विश्वविद्यालय, विद्यालय या प्रशिक्षण संस्था के क्षेत्रीय सर्वेक्षण का परिणाम नहीं माना जाना चाहिए।

दूसरी सीमा यह है कि रोजगारपरकता को निर्धारित करने वाले सभी सामाजिक और आर्थिक कारकों को प्रतिरूप में सम्मिलित नहीं किया गया। पारिवारिक आय, भौगोलिक स्थिति, सामाजिक नेटवर्क, भाषा, क्षेत्रीय रोजगार अवसर और लिंग आधारित श्रम बाजार असमानता जैसे तत्व भी वास्तविक रोजगार परिणामों को प्रभावित कर सकते हैं।

तीसरी सीमा यह है कि कौशल-संरेखण को समय के साथ बदलने वाला तत्व माना गया है, परंतु वर्तमान प्रस्तावित विश्लेषण मुख्यतः एक समय-बिंदु पर आधारित है।

चौथी सीमा यह है कि उद्योग की अपेक्षाएँ क्षेत्र-दर-क्षेत्र बदल सकती हैं। इसलिए किसी एक कौशल सूचकांक को पूरे देश में समान रूप से लागू करना उचित नहीं होगा।

पाँचवीं सीमा यह है कि व्यवहारिक दक्षता का पूर्ण मूल्यांकन केवल प्रश्नावली या अंक आधारित संरचना से नहीं किया जा सकता। इसके लिए प्रत्यक्ष कार्य निष्पादन और पर्यवेक्षण आधारित मूल्यांकन आवश्यक होगा।

भावी अनुसंधान की दिशा

भावी अध्ययन वास्तविक विद्यालयों, महाविद्यालयों, औद्योगिक प्रशिक्षण संस्थानों और कौशल केंद्रों से बहु-राज्यीय क्षेत्रीय आँकड़े एकत्र कर सकते हैं।

विशेष रूप से निम्न दिशा उपयोगी हो सकती है:

- प्रशिक्षण से रोजगार तक शिक्षार्थियों का दीर्घकालिक अनुश्रवण
- विभिन्न राज्यों के कौशल-संरेखण की तुलना
- स्थानीय उद्योगों के आधार पर कौशल मांग मानचित्रण
- प्रशिक्षुता और बिना प्रशिक्षुता वाले समूहों का तुलनात्मक अध्ययन
- पूर्व अर्जित अधिगम की मान्यता का रोजगार परिणामों पर प्रभाव
- ग्रामीण और शहरी कौशल पारिस्थितिकी का तुलनात्मक विश्लेषण
- कौशल मूल्यांकन में कृत्रिम बुद्धिमत्ता आधारित अनुकूलनशील परीक्षण
- बदलते रोजगार संकेतकों के आधार पर पाठ्यक्रम संशोधन की स्वचालित प्रणाली

भविष्य में एक ऐसा राष्ट्रीय गतिशील कौशल-संरेखण तंत्र विकसित किया जा सकता है जो विभिन्न क्षेत्रों की रोजगार मांग, प्रशिक्षण परिणाम और विद्यार्थियों की दक्षता को समय-समय पर जोड़कर कौशल कार्यक्रमों के अद्यतन की अनुशंसा करे।

निष्कर्ष

राष्ट्रीय शिक्षा नीति २०२० ने भारतीय शिक्षा व्यवस्था में व्यावसायिक शिक्षा को मुख्यधारा से जोड़ने की एक महत्वपूर्ण संरचनात्मक दिशा प्रदान की है। शिक्षा और कौशल के बीच विभाजन कम करना, कार्य-अनुभव को मान्यता देना, ऋण आधारित गतिशीलता विकसित करना और योग्यता को अधिगम परिणामों से जोड़ना इस परिवर्तन के प्रमुख आधार हैं।

वर्तमान अध्ययन ने यह प्रतिपादित किया कि व्यावसायिक शिक्षा की सफलता केवल पाठ्यक्रम की उपलब्धता, नामांकन या प्रमाणपत्र वितरण से नहीं मापी जानी चाहिए। वास्तविक प्रश्न यह है कि विद्यार्थी द्वारा अर्जित कौशल रोजगार की वास्तविक अपेक्षाओं से कितना मेल खाता है।

प्रस्तावित विश्लेषण में तकनीकी दक्षता, उद्योग-संरेखण, कार्यस्थल अनुभव, समस्या-समाधान, संचार और अनुकूलनशीलता को संयुक्त रूप से रोजगारपरक तैयारी के निर्धारक के रूप में देखा गया।

अध्ययन के प्रायोगिक निष्कर्ष यह संकेत करते हैं कि उद्योग-संरेखण और कार्यस्थल अनुभव तकनीकी दक्षता के प्रभाव को उल्लेखनीय रूप से सुदृढ़ कर सकते हैं। इसलिए व्यावसायिक शिक्षा को केवल कौशल प्रशिक्षण कार्यक्रम के रूप में नहीं, बल्कि शिक्षा से कार्य की ओर संक्रमण की एक समेकित प्रणाली के रूप में विकसित किया जाना चाहिए।

नीतिगत स्तर पर यह आवश्यक है कि स्थानीय रोजगार क्षेत्र की मांग का नियमित कौशल मानचित्रण किया जाए, प्रशिक्षण संस्थानों और उद्योगों के बीच सक्रिय साझेदारी बढ़ाई जाए, प्रशिक्षुता को व्यापक बनाया जाए तथा विद्यार्थियों की वास्तविक कार्य-दक्षता का निरंतर मूल्यांकन किया जाए।

इस प्रकार राष्ट्रीय शिक्षा नीति २०२० की व्यावसायिक शिक्षा संबंधी दृष्टि तभी व्यापक रोजगारपरक परिणाम प्रदान कर सकेगी जब प्रशिक्षण की मात्रा से आगे बढ़कर **कौशल की गुणवत्ता, प्रासंगिकता, हस्तांतरणीयता और उद्योग-संरेखण** को शिक्षा व्यवस्था के केंद्रीय मूल्यांकन मानदंड के रूप में स्थापित किया जाए।

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- *भारत सरकार, शिक्षा मंत्रालय। (2020). National Education Policy 2020. नई दिल्ली: शिक्षा मंत्रालय। नीति में व्यावसायिक शिक्षा को मुख्यधारा में एकीकृत करने, कक्षा ६–८ में व्यावसायिक अनुभव, स्थानीय कौशल आवश्यकताओं के मानचित्रण, उद्योग सहयोग तथा प्रशिक्षुता पर स्पष्ट प्रावधान दिए गए हैं।*
  राष्ट्रीय शिक्षा नीति २०२० का आधिकारिक दस्तावेज़
- *विश्वविद्यालय अनुदान आयोग। (2023). National Credit Framework. नई दिल्ली: विश्वविद्यालय अनुदान आयोग। यह ढाँचा सामान्य शिक्षा, व्यावसायिक शिक्षा, कौशल प्रशिक्षण और अनुभव से अर्जित अधिगम के लिए ऋण संचय, हस्तांतरण तथा शैक्षणिक समतुल्यता की व्यवस्था प्रस्तुत करता है।*
  राष्ट्रीय ऋण ढाँचा—आधिकारिक दस्तावेज़
- *राष्ट्रीय व्यावसायिक शिक्षा और प्रशिक्षण परिषद। (2023). National Skills Qualification Framework. भारत सरकार। संशोधित ढाँचा ६ जून २०२३ को अधिसूचित किया गया और यह ज्ञान, कौशल, अभिरुचि तथा उत्तरदायित्व को अधिगम परिणामों के आधार पर संगठित करता है।*
  राष्ट्रीय कौशल योग्यता ढाँचा—आधिकारिक अधिसूचना
- *राष्ट्रीय व्यावसायिक शिक्षा और प्रशिक्षण परिषद। (2026). National Skills Qualification Framework. इस आधिकारिक विवरण में व्यावसायिक शिक्षा, सामान्य शिक्षा, तकनीकी शिक्षा और श्रम बाजार के बीच प्रवेश एवं निकास मार्ग, उद्योग सहभागिता, आजीवन अधिगम और पूर्व अर्जित अधिगम की मान्यता को प्रमुख तत्व बताया गया है।*
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  शिक्षा मंत्रालय वार्षिक प्रतिवेदन २०२४–२५
- *भारत सरकार, शिक्षा मंत्रालय। (2025). National Education Policy, 2020 Initiatives. यह आधिकारिक पृष्ठ राष्ट्रीय शिक्षा नीति के अंतर्गत विद्यालयी तथा उच्च शिक्षा संबंधी क्रियान्वयन पहलों का विवरण प्रस्तुत करता है।*
  राष्ट्रीय शिक्षा नीति क्रियान्वयन पहलें

अध्ययन के प्रायोगिक निष्कर्ष यह संकेत करते हैं कि उद्योग-संरेखण और कार्यस्थल अनुभव तकनीकी दक्षता के प्रभाव को उल्लेखनीय रूप से सुदृढ़ कर सकते हैं। इसलिए व्यावसायिक शिक्षा को केवल कौशल प्रशिक्षण कार्यक्रम के रूप में नहीं, बल्कि शिक्षा से कार्य की ओर संक्रमण की एक समेकित प्रणाली के रूप में विकसित किया जाना चाहिए।

नीतिगत स्तर पर यह आवश्यक है कि स्थानीय रोजगार क्षेत्र की मांग का नियमित कौशल मानचित्रण किया जाए, प्रशिक्षण संस्थानों और उद्योगों के बीच सक्रिय साझेदारी बढ़ाई जाए, प्रशिक्षुता को व्यापक बनाया जाए तथा विद्यार्थियों की वास्तविक कार्य-दक्षता का निरंतर मूल्यांकन किया जाए।

इस प्रकार राष्ट्रीय शिक्षा नीति २०२० की व्यावसायिक शिक्षा संबंधी दृष्टि तभी व्यापक रोजगारपरक परिणाम प्रदान कर सकेगी जब प्रशिक्षण की मात्रा से आगे बढ़कर **कौशल की गुणवत्ता, प्रासंगिकता, हस्तांतरणीयता और उद्योग-संरेखण** को शिक्षा व्यवस्था के केंद्रीय मूल्यांकन मानदंड के रूप में स्थापित किया जाए।

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- *राष्ट्रीय व्यावसायिक शिक्षा और प्रशिक्षण परिषद। (2026). National Skills Qualification Framework. इस आधिकारिक विवरण में व्यावसायिक शिक्षा, सामान्य शिक्षा, तकनीकी शिक्षा और श्रम बाजार के बीच प्रवेश एवं निकास मार्ग, उद्योग सहभागिता, आजीवन अधिगम और पूर्व अर्जित अधिगम की मान्यता को प्रमुख तत्व बताया गया है।*
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  राष्ट्रीय शिक्षा नीति क्रियान्वयन पहलें

अध्याय 16: NEP 2020 के संदर्भ में उच्च शिक्षा में बहुविषयक अधिगम की संभावनाएँ

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सारांश— राष्ट्रीय शिक्षा नीति २०२० ने भारतीय उच्च शिक्षा में विषयगत पृथक्करण को कम करते हुए समग्र और बहुविषयक अधिगम को संस्थागत रूप देने की दिशा निर्धारित की है। प्रस्तुत अध्ययन उच्च शिक्षा में बहुविषयक अधिगम की संभावनाओं का विश्लेषण विद्यार्थी चयन-स्वतंत्रता, पाठ्यचर्या लचीलेपन, शिक्षक सहयोग, संस्थागत तैयारी और अधिगम-गुणवत्ता के संयुक्त संदर्भ में करता है। अध्ययन का प्रमुख शोध-अंतर यह है कि उपलब्ध विमर्श में बहुविषयक शिक्षा को प्रायः नीतिगत उद्देश्य अथवा पाठ्यक्रम पुनर्गठन के रूप में देखा गया है, जबकि उसके कार्यान्वयन की परस्पर संबद्ध संस्थागत दशाओं का समेकित परीक्षण सीमित है। शोध में यह मान्यता रखी गई है कि विषयों की संख्या बढ़ा देना अपने आप में बहुविषयक अधिगम नहीं है; वास्तविक प्रभाव विषयों के बीच ज्ञान-संबंध स्थापित करने और विद्यार्थी को सार्थक चयन प्रदान करने से उत्पन्न होता है। प्रस्तावित अध्ययन कला, विज्ञान, सामाजिक विज्ञान, वाणिज्य, प्रौद्योगिकी, स्वास्थ्य और भारतीय ज्ञान परंपराओं के बीच अधिगम-संबंधों को उच्च शिक्षा की नई संरचना से जोड़ता है। इसमें बहुविषयक अधिगम की प्रभावशीलता को शैक्षणिक सहभागिता, समस्या-समाधान क्षमता, ज्ञान-संयोजन, अधिगम स्वायत्तता और व्यावहारिक अनुप्रयोग जैसे संकेतकों से समझने का आधार विकसित किया गया है। अध्ययन यह भी स्पष्ट करता है कि संसाधन-असमानता, शिक्षक तैयारी, समय-सारिणी समन्वय और संस्थागत जड़ता बहुविषयक व्यवस्था की प्रभावशीलता को सीमित कर सकते हैं।

मुख्य शब्द— बहुविषयक अधिगम, उच्च शिक्षा, राष्ट्रीय शिक्षा नीति २०२०, पाठ्यचर्या लचीलापन, विद्यार्थी स्वायत्तता, संस्थागत तैयारी

परिचय

भारतीय उच्च शिक्षा लंबे समय तक ऐसे विषयगत ढाँचे के अंतर्गत विकसित हुई जिसमें विद्यार्थी सामान्यतः किसी एक संकाय, विषय अथवा व्यावसायिक क्षेत्र के भीतर अपनी शिक्षा पूरी करते रहे। विज्ञान, कला, वाणिज्य, प्रौद्योगिकी, विधि और स्वास्थ्य संबंधी अध्ययन प्रायः पृथक संस्थागत और पाठ्यचर्यात्मक सीमाओं में संचालित होते रहे। इस व्यवस्था ने विषय-विशेषज्ञता के विकास में महत्त्वपूर्ण योगदान दिया, किंतु जटिल सामाजिक, आर्थिक, तकनीकी और पर्यावरणीय समस्याओं के समाधान के लिए आवश्यक ज्ञान-संयोजन को पर्याप्त स्थान नहीं मिल सका। समकालीन समाज में जलवायु परिवर्तन, सार्वजनिक स्वास्थ्य, डिजिटल शासन, आर्थिक असमानता, सामाजिक व्यवहार, सतत विकास और कृत्रिम बुद्धिमत्ता जैसे प्रश्न किसी एक विषय की सीमा में नहीं समझे जा सकते। इन्हें समझने के लिए विविध ज्ञान क्षेत्रों के मध्य सक्रिय संवाद आवश्यक है।

राष्ट्रीय शिक्षा नीति २०२० ने इसी आवश्यकता को स्वीकार करते हुए उच्च शिक्षा के लिए बड़े, समग्र और बहुविषयक संस्थानों की परिकल्पना की है। नीति में उच्च शिक्षा के विखंडन को कम करने, विषयों के बीच कठोर सीमाओं को शिथिल करने, विद्यार्थी को व्यापक विषय-विकल्प देने और शिक्षण, अनुसंधान तथा नवाचार को परस्पर जोड़ने पर बल दिया गया है। शिक्षा मंत्रालय के आधिकारिक नीति दस्तावेज में बहुविषयक विश्वविद्यालयों और महाविद्यालयों की दिशा में परिवर्तन को उच्च शिक्षा व्यवस्था के प्रमुख संरचनात्मक सुधारों में रखा गया है।

बहुविषयक अधिगम का मूल अर्थ केवल एक विद्यार्थी द्वारा विभिन्न विषयों का अध्ययन करना नहीं है। इसकी सार्थकता तब उत्पन्न होती है जब भिन्न ज्ञान क्षेत्रों की अवधारणाओं, पद्धतियों और विश्लेषणात्मक दृष्टियों को किसी समस्या, विचार अथवा सामाजिक आवश्यकता के संदर्भ में एक-दूसरे से जोड़ा जाए। उदाहरण के लिए पर्यावरणीय संकट का अध्ययन केवल प्राकृतिक विज्ञान तक सीमित न रहकर अर्थव्यवस्था, विधि, समाजशास्त्र, सार्वजनिक नीति, भूगोल और स्थानीय समुदायों के ज्ञान से जुड़ सकता है। इसी प्रकार स्वास्थ्य संबंधी शिक्षा में जैविक ज्ञान के साथ मनोविज्ञान, समाज, सांख्यिकी, प्रौद्योगिकी और नैतिकता का समावेश अधिक समग्र समझ उत्पन्न कर सकता है।

राष्ट्रीय शिक्षा नीति २०२० का एक महत्त्वपूर्ण पक्ष यह भी है कि व्यावसायिक और सामान्य शिक्षा के बीच ऐतिहासिक विभाजन को कम किया जाए। नीति के अनुसार व्यावसायिक शिक्षा को व्यापक उच्च शिक्षा व्यवस्था का अभिन्न भाग बनाते हुए संस्थानों को क्रमशः बहुविषयक स्वरूप ग्रहण करना चाहिए। इस दृष्टिकोण का उद्देश्य ऐसे स्नातकों का निर्माण करना है जो अपने प्रमुख विषय में दक्ष होने के साथ-साथ आलोचनात्मक चिंतन, नैतिक निर्णय, संप्रेषण, रचनात्मकता और सामाजिक उत्तरदायित्व जैसी व्यापक क्षमताएँ विकसित कर सकें।

वर्ष २०२१ के बाद बहुविषयक उच्च शिक्षा को क्रियान्वित करने की दिशा में कई संरचनात्मक पहल आगे बढ़ीं। इनमें शैक्षणिक अंकों के संचयन की व्यवस्था, बहु-प्रवेश एवं बहु-निर्गमन की अवधारणा, स्नातक कार्यक्रमों के लिए पाठ्यचर्या एवं अंक-रूपरेखा, राष्ट्रीय अंक-रूपरेखा और उच्च शिक्षा संस्थानों को बहुविषयक संस्थानों में परिवर्तित करने से संबंधित दिशानिर्देश प्रमुख हैं। शिक्षा मंत्रालय और विश्वविद्यालय अनुदान आयोग के आधिकारिक अभिलेखों में इन पहलों को राष्ट्रीय शिक्षा नीति के उच्च शिक्षा संबंधी क्रियान्वयन से जोड़ा गया है।

स्नातक पाठ्यचर्या एवं अंक-रूपरेखा का विद्यार्थी-केंद्रित स्वरूप इस परिवर्तन का विशेष आधार है। इसके अंतर्गत विद्यार्थी को अपनी रुचि के अनुसार विभिन्न अध्ययन क्षेत्रों का चयन करने, प्रमुख और गौण विषयों के संयोजन विकसित करने तथा अध्ययन-पथ में अधिक लचीलापन प्राप्त करने की दिशा दी गई है। विश्वविद्यालय अनुदान आयोग के आधिकारिक विवरण में बहुविषयक दृष्टिकोण, लचीली

विषय-चयन व्यवस्था और बहु-प्रवेश तथा बहु-निर्गमन को इस संरचना के प्रमुख अंगों के रूप में स्पष्ट किया गया है।

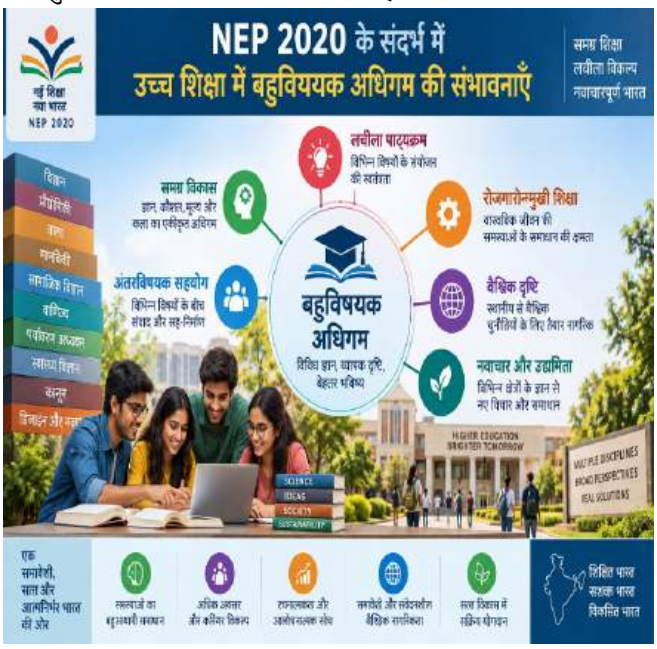


Fig .1: बहुविषयक उच्च शिक्षा: समग्र ज्ञान, नवाचार और भविष्य की नई दिशा

फिर भी नीति का औपचारिक प्रावधान और उसका वास्तविक शैक्षणिक प्रभाव एक समान नहीं माना जा सकता। किसी विश्वविद्यालय में अनेक विषय उपलब्ध होना इस बात की गारंटी नहीं देता कि विद्यार्थी उन विषयों के मध्य सार्थक बौद्धिक संबंध स्थापित कर पाएगा। यदि समय-सारिणी, विभागीय समन्वय, शिक्षक उपलब्धता, पाठ्यचर्या संरचना, परामर्श प्रणाली और मूल्यांकन पद्धति विषयगत विभाजन को ही बनाए रखते हैं, तो बहुविषयकता केवल प्रशासनिक विकल्प बनकर रह सकती है।

यही स्थिति प्रस्तुत अध्ययन के मूल शोध-अंतर को जन्म देती है। वर्तमान विमर्श में राष्ट्रीय शिक्षा नीति २०२० के अंतर्गत बहुविषयकता की आवश्यकता, लचीले पाठ्यक्रम और संस्थागत पुनर्गठन पर पर्याप्त चर्चा उपलब्ध है, किंतु यह प्रश्न अपेक्षाकृत कम विश्लेषित हुआ है कि **विद्यार्थी चयन-स्वतंत्रता, विभागों के बीच शिक्षक सहयोग, पाठ्यक्रमीय अंतर्संबंध, संस्थागत तैयारी और शैक्षणिक संसाधनों की उपलब्धता मिलकर वास्तविक अधिगम परिणामों को किस प्रकार प्रभावित करते हैं।** अतः प्रस्तावित अध्ययन बहुविषयकता को केवल नीति-सुधार के रूप में नहीं, बल्कि एक बहुस्तरीय शैक्षणिक प्रक्रिया के रूप में देखता है।

इस अध्ययन का प्रमुख उद्देश्य यह समझना है कि राष्ट्रीय शिक्षा नीति २०२० के संदर्भ में बहुविषयक अधिगम उच्च शिक्षा में विद्यार्थी की ज्ञान-संयोजन क्षमता, समस्या-समाधान प्रवृत्ति, शैक्षणिक सहभागिता, अधिगम स्वायत्तता और व्यावहारिक समझ को किस सीमा तक सुदृढ़ कर सकता है। इसके साथ ही अध्ययन संस्थागत परिस्थितियों को मध्यवर्ती कारक मानता है, क्योंकि समान नीति व्यवस्था के बावजूद विभिन्न उच्च शिक्षा संस्थानों में परिणाम भिन्न हो सकते हैं।

इस प्रकार प्रस्तुत शोध नीति-स्तर की अपेक्षाओं और संस्थागत स्तर की वास्तविकताओं के बीच संबंध स्थापित करता है। इसकी केंद्रीय धारणा यह है कि सफल बहुविषयकता के लिए विषय-विकल्प की उपलब्धता पर्याप्त नहीं है; विद्यार्थी को उपयुक्त शैक्षणिक परामर्श, पाठ्यक्रमों के बीच स्पष्ट ज्ञान-संबंध, सहयोगात्मक शिक्षण, समन्वित मूल्यांकन और संस्थागत समर्थन भी आवश्यक है।

साहित्य समीक्षा

२.१ बहुविषयक शिक्षा की वैचारिक पृष्ठभूमि

बहुविषयक अधिगम उस शैक्षिक दृष्टिकोण को अभिव्यक्त करता है जिसमें विद्यार्थी किसी समस्या अथवा ज्ञान क्षेत्र को अनेक विषयगत दृष्टियों से समझता है। पारंपरिक विषय-केंद्रित शिक्षा गहन विशेषज्ञता विकसित करती है, जबकि बहुविषयक शिक्षा उस विशेषज्ञता को व्यापक सामाजिक, वैज्ञानिक और मानवीय संदर्भ से जोड़ने का अवसर देती है। उच्च शिक्षा में इसका महत्त्व इसलिए बढ़ा है क्योंकि वर्तमान ज्ञान-समाज में समस्याओं की प्रकृति परस्पर संबद्ध हो गई है। स्वास्थ्य को केवल चिकित्सा विज्ञान, आर्थिक विकास को केवल अर्थशास्त्र, तकनीकी परिवर्तन को केवल संगणकीय अध्ययन और पर्यावरणीय संकट को केवल प्राकृतिक विज्ञान के आधार पर पूर्णतः नहीं समझा जा सकता। विषयों के बीच संवाद विद्यार्थी को कारणों, परिणामों और संभावित समाधानों की व्यापक संरचना समझने में सहायता करता है।

२.२ राष्ट्रीय शिक्षा नीति २०२० में बहुविषयकता

राष्ट्रीय शिक्षा नीति २०२० उच्च शिक्षा में बहुविषयक संरचना को व्यापक संस्थागत सुधार से जोड़ती है। इसका लक्ष्य ऐसे बड़े उच्च शिक्षा संस्थान विकसित करना है जिनमें विविध विषयों में शिक्षण और अनुसंधान उपलब्ध हो तथा विद्यार्थी किसी एक संकीर्ण विषयगत सीमा में बाध्य न हो। नीति स्वायत्तता, समग्र शिक्षा, अनुसंधान और विद्यार्थी अनुभव में सुधार को भी इसी परिवर्तन का हिस्सा मानती है।

नीति में व्यावसायिक और सामान्य शिक्षा के एकीकरण पर विशेष बल दिया गया है। इससे चिकित्सा, कृषि, विधि, प्रौद्योगिकी अथवा अन्य व्यावसायिक क्षेत्रों के विद्यार्थी मानवीय और सामाजिक विषयों से जुड़ सकते हैं, जबकि कला अथवा सामाजिक विज्ञान के विद्यार्थी वैज्ञानिक और तकनीकी ज्ञान से परिचित हो सकते हैं। यह संरचना उच्च शिक्षा को केवल रोजगार-उन्मुख प्रशिक्षण न मानकर व्यक्ति के व्यापक बौद्धिक और सामाजिक विकास की प्रक्रिया के रूप में पुनर्परिभाषित करती है।

२.३ पाठ्यचर्या लचीलापन और विद्यार्थी चयन

वर्ष २०२२ के बाद विकसित स्नातक पाठ्यचर्या एवं अंक-रूपरेखा बहुविषयक अधिगम को व्यवहारिक आधार प्रदान करने वाली महत्त्वपूर्ण पहल है। इसमें विद्यार्थी की रुचि और शैक्षणिक पथ को अधिक महत्त्व देते हुए विषय चयन में लचीलापन बढ़ाने की दिशा दी गई है। विश्वविद्यालय अनुदान आयोग ने इसे बहुविषयक दृष्टिकोण और विद्यार्थी-केंद्रित उच्च शिक्षा से जोड़ा है।

यह परिवर्तन महत्त्वपूर्ण है क्योंकि पूर्ववर्ती व्यवस्था में विद्यार्थी का विषय-विकल्प प्रवेश के समय लिए गए निर्णय से काफी हद तक निर्धारित हो जाता था। नई रूपरेखाएँ इस कठोरता को कम करने की संभावना उत्पन्न करती हैं। फिर भी चयन की स्वतंत्रता तभी प्रभावी होती है जब विद्यार्थी को विषयों की प्रकृति, संभावित संयोजन और भविष्य की शैक्षणिक दिशा के बारे में पर्याप्त परामर्श उपलब्ध हो।

२.४ संस्थागत बहुविषयकता और संगठनात्मक परिवर्तन

विश्वविद्यालय अनुदान आयोग द्वारा उच्च शिक्षा संस्थानों को बहुविषयक स्वरूप में परिवर्तित करने से संबंधित दिशानिर्देशों का प्रकाशन यह संकेत देता है कि बहुविषयकता केवल पाठ्यचर्या परिवर्तन नहीं, बल्कि संस्थागत पुनर्संरचना का विषय है। आयोग की आधिकारिक प्रकाशन

सूची में बहुविषयक संस्थानों में परिवर्तन, बहु-प्रवेश एवं बहु-निर्गमन, शोध एवं विकास इकाइयों और अन्य शैक्षणिक सुधारों के लिए पृथक दिशानिर्देश सम्मिलित हैं।

इससे स्पष्ट होता है कि सफल क्रियान्वयन के लिए प्रशासनिक ढाँचे, शिक्षक नियुक्ति, विभागीय सहयोग, भौतिक संसाधन, विद्यार्थी परामर्श और मूल्यांकन प्रणाली में समानांतर परिवर्तन आवश्यक हैं। यदि विभाग अपने पाठ्यक्रमों, समय-सारिणी और संसाधनों को पूर्णतः पृथक रखते हैं, तो विद्यार्थी के लिए विषयों के बीच वास्तविक आवागमन कठिन बना रहेगा।

२.५ शिक्षक की भूमिका और सहयोगात्मक शिक्षण

बहुविषयक व्यवस्था शिक्षक की भूमिका को भी परिवर्तित करती है। एकल विषय पढ़ाने की पारंपरिक भूमिका के साथ शिक्षक को अन्य ज्ञान क्षेत्रों के शिक्षकों के साथ सहयोग करना पड़ सकता है। किसी साझा समस्या पर संयुक्त शिक्षण, परियोजना-आधारित कार्य, क्षेत्रीय अध्ययन और विभिन्न विषयों को जोड़ने वाले अधिगम कार्य इस सहयोग के संभावित माध्यम हैं।

यहाँ एक व्यावहारिक चुनौती सामने आती है। शिक्षक अपने विषय में उच्च विशेषज्ञता रख सकते हैं, किंतु बहुविषयक पाठ्यक्रम निर्माण और संयुक्त मूल्यांकन के लिए पृथक शैक्षणिक तैयारी की आवश्यकता होती है। अतः शिक्षक विकास को बहुविषयक सुधार से अलग नहीं देखा जा सकता।

२.६ विद्यार्थी स्वायत्तता और अधिगम परिणाम

बहुविषयक व्यवस्था में विद्यार्थी केवल पूर्वनिर्धारित पाठ्यक्रम का निष्क्रिय उपभोक्ता नहीं रहता, बल्कि अपने अध्ययन-पथ के निर्माण में सहभागी बनता है। यह स्वायत्तता उसकी रुचि, जिज्ञासा और उत्तरदायित्व को बढ़ा सकती है। भिन्न विषयों से प्राप्त ज्ञान का संयोजन समस्या-समाधान तथा सृजनात्मक चिंतन को भी सुदृढ़ कर सकता है।

इसके विपरीत अत्यधिक विकल्प बिना शैक्षणिक मार्गदर्शन के भ्रम उत्पन्न कर सकते हैं। इसलिए चयन की स्वतंत्रता और संरचित परामर्श के बीच संतुलन आवश्यक है। बहुविषयकता की गुणवत्ता का आकलन केवल उपलब्ध विषयों की संख्या से नहीं, बल्कि इस बात से किया जाना चाहिए कि विद्यार्थी उन विषयों को किस प्रकार जोड़ता और उपयोग करता है।

२.७ भारतीय ज्ञान परंपराओं और समकालीन विषयों का संबंध

हाल के उच्च शिक्षा सुधारों में भारतीय ज्ञान परंपराओं को पाठ्यचर्या में समाहित करने और जीवन-कौशल, पर्यावरणीय शिक्षा, सामाजिक उत्तरदायित्व तथा सामुदायिक सहभागिता से संबंधित दिशानिर्देश भी विकसित किए गए हैं। विश्वविद्यालय अनुदान आयोग की आधिकारिक दिशानिर्देश सूची में भारतीय ज्ञान, पर्यावरण शिक्षा, जीवन-कौशल तथा सामाजिक उत्तरदायित्व से संबंधित पहलों का उल्लेख मिलता है।

यह प्रवृत्ति बहुविषयक अधिगम को अधिक व्यापक बनाती है। उदाहरणतः पर्यावरणीय ज्ञान को स्थानीय परंपराओं, इतिहास, अर्थव्यवस्था और प्राकृतिक विज्ञान के साथ जोड़ना, अथवा स्वास्थ्य को योग, मनोविज्ञान, जैवविज्ञान और सामाजिक व्यवहार से जोड़ना संदर्भ-संवेदनशील उच्च शिक्षा विकसित कर सकता है।

प्रस्तावित कार्यविधि

प्रस्तुत अध्ययन के लिए मिश्रित अनुसंधान पद्धति प्रस्तावित की गई है, जिसमें मात्रात्मक तथा गुणात्मक दोनों प्रकार के साक्ष्यों को सम्मिलित किया जाएगा। अध्ययन का उद्देश्य केवल यह ज्ञात करना नहीं है कि उच्च शिक्षा संस्थानों में बहुविषयक पाठ्यक्रम उपलब्ध हैं अथवा नहीं, बल्कि यह समझना है कि उनकी उपलब्धता विद्यार्थी के वास्तविक अधिगम अनुभव, ज्ञान-संयोजन, शैक्षणिक सहभागिता, स्वायत्तता और समस्या-समाधान क्षमता को किस प्रकार प्रभावित करती है। इस कारण अनुसंधान संरचना को संस्थागत, शिक्षक तथा विद्यार्थी—तीनों स्तरों पर विकसित किया गया है।

अध्ययन में उच्च शिक्षा संस्थानों को तीन श्रेणियों में विभाजित किया जाएगा। प्रथम श्रेणी में वे संस्थान होंगे जहाँ बहुविषयक पाठ्यक्रमों का अपेक्षाकृत व्यापक क्रियान्वयन हो चुका है। द्वितीय श्रेणी में वे संस्थान शामिल किए जाएँगे जहाँ यह व्यवस्था आंशिक रूप से लागू है। तृतीय श्रेणी में वे संस्थान होंगे जहाँ विषय चयन और विभागीय संरचना अभी भी अपेक्षाकृत पारंपरिक स्वरूप में संचालित होती है। इस वर्गीकरण का उद्देश्य बहुविषयकता की विभिन्न अवस्थाओं के बीच अधिगम परिणामों की तुलना करना है।

प्रस्तावित नमूने में स्नातक स्तर के लगभग छह सौ विद्यार्थियों को सम्मिलित किया जा सकता है। इसके अतिरिक्त लगभग नब्बे शिक्षकों और तीस शैक्षणिक प्रशासकों से भी जानकारी प्राप्त की जाएगी। विद्यार्थी नमूने को कला, विज्ञान, वाणिज्य, सामाजिक विज्ञान, प्रौद्योगिकी तथा स्वास्थ्य संबंधी अध्ययन क्षेत्रों में संतुलित रूप से वितरित किया जाएगा। चयन के लिए स्तरीकृत यादृच्छिक पद्धति का प्रयोग प्रस्तावित है, ताकि विभिन्न विषय समूहों और संस्थागत प्रकारों का पर्याप्त प्रतिनिधित्व सुनिश्चित किया जा सके।

विद्यार्थी स्तर पर पाँच प्रमुख आयामों का मापन किया जाएगा—विषय चयन स्वतंत्रता, अंतर्विषयक संपर्क, शिक्षक सहयोग का अनुभव, ज्ञान-संयोजन क्षमता और अधिगम स्वायत्तता। इसके अतिरिक्त समस्या-समाधान, समूह आधारित परियोजना सहभागिता, वास्तविक जीवन अनुप्रयोग और शैक्षणिक संतुष्टि को परिणामकारी संकेतकों के रूप में शामिल किया जाएगा।

शिक्षकों के लिए पृथक मापन उपकरण विकसित किया जाएगा, जिसमें संयुक्त पाठ्यक्रम निर्माण, सह-शिक्षण, अन्य विभागों के साथ सहयोग, मूल्यांकन समन्वय और बहुविषयक प्रशिक्षण से संबंधित प्रश्न सम्मिलित होंगे। संस्थागत स्तर पर समय-सारिणी लचीलापन, विषय विकल्पों की उपलब्धता, परामर्श व्यवस्था, शैक्षणिक संसाधन, डिजिटल अधिगम साधन और विभागीय समन्वय का परीक्षण किया जाएगा।

गुणात्मक भाग के अंतर्गत चयनित विद्यार्थियों, शिक्षकों और प्रशासकों के अर्ध-संरचित साक्षात्कार लिए जाएँगे। इन साक्षात्कारों का उद्देश्य मात्रात्मक निष्कर्षों के पीछे उपस्थित अनुभवात्मक कारणों की पहचान करना होगा। उदाहरणतः यदि किसी संस्थान में विषय विकल्प पर्याप्त हैं, फिर भी विद्यार्थी बहुविषयक अधिगम का लाभ नहीं उठा रहे, तो साक्षात्कार यह स्पष्ट कर सकते हैं कि समस्या समय-सारिणी, परामर्श की कमी, मूल्यांकन पद्धति अथवा विषयों के बीच कमजोर संबंध के कारण उत्पन्न हो रही है।

प्रायोगिक व्यवस्था

४.१ आँकड़ा-संग्रह संरचना

अध्ययन के लिए प्राथमिक आँकड़े तीन स्रोतों से एकत्र किए जाएँगे। विद्यार्थी प्रश्नावली से अधिगम व्यवहार और अनुभव से संबंधित संकेतक प्राप्त किए जाएँगे। शिक्षक प्रश्नावली से सहयोगात्मक शिक्षण और

संस्थागत समर्थन का आकलन किया जाएगा। प्रशासकीय प्रपत्रों से पाठ्यक्रम संरचना, उपलब्ध विषय विकल्प, विभागों के बीच पंजीकरण और बहुविषयक गतिविधियों से संबंधित जानकारी एकत्र की जाएगी। प्रत्येक विद्यार्थी के लिए निम्न प्रकार के संकेतक प्रस्तावित हैं—

- प्रमुख और गौण विषयों के बीच विषयगत दूरी,
- चुने गए वैकल्पिक विषयों की विविधता,
- संयुक्त परियोजनाओं में सहभागिता,
- विभागों के बाहर लिए गए पाठ्यक्रमों की संख्या,
- समस्या-आधारित अधिगम गतिविधियों में भागीदारी,
- विषय संयोजन की समझ,
- स्व-निर्देशित अधिगम का स्तर,
- शैक्षणिक सहभागिता,
- अनुप्रयोग आधारित प्रदर्शन।

इन संकेतकों को किसी व्यक्तिगत पहचान से अलग रखकर सांकेतिक रूप में संरक्षित किया जाएगा।

४.२ आँकड़ा पूर्व-संसाधन

आँकड़ों की गुणवत्ता सुनिश्चित करने के लिए प्रारंभिक शुद्धिकरण किया जाएगा। अधूरे उत्तरों, परस्पर विरोधी प्रविष्टियों और अत्यधिक असामान्य प्रतिक्रियाओं की जाँच की जाएगी। यदि किसी प्रश्नावली में निर्धारित सीमा से अधिक उत्तर अनुपस्थित होंगे तो उसे विश्लेषण से बाहर रखा जाएगा।

मापन मानों को तुलनीय बनाने के लिए मानकीकरण किया जाएगा। श्रेणीगत उत्तरों को क्रमबद्ध संख्यात्मक रूप दिया जाएगा। विषय विविधता के लिए एक संयोजित सूचकांक बनाया जाएगा, जिसमें विद्यार्थी द्वारा चुने गए ज्ञान क्षेत्रों की संख्या तथा उनके विषयगत अंतर को सम्मिलित किया जाएगा।

गुणात्मक साक्षात्कारों को विषयगत वर्गों में विभाजित किया जाएगा। प्रमुख वर्गों में पाठ्यचर्या लचीलापन, संस्थागत अवरोध, शिक्षक सहयोग, विद्यार्थी भ्रम, ज्ञान-संयोजन, संसाधन उपलब्धता और अधिगम लाभ सम्मिलित होंगे।

४.३ विश्लेषणात्मक प्रतिरूप की संरचना

इस अध्ययन में पारंपरिक सांख्यिकीय परीक्षणों के साथ एक व्याख्येय संगणकीय प्रतिरूप प्रस्तावित है। इसका उद्देश्य विद्यार्थियों में उच्च बहुविषयक अधिगम परिणाम की संभावना का अनुमान लगाना और यह पहचानना है कि कौन-से कारक उस परिणाम में सर्वाधिक योगदान देते हैं।

प्रतिरूप में निम्न प्रमुख निवेश संकेतक शामिल किए जाएँगे—

पाठ्यचर्या लचीलापन, विषय-विविधता, शिक्षक सहयोग, परामर्श समर्थन, शैक्षणिक संसाधन, विद्यार्थी स्वायत्तता, परियोजना सहभागिता और विभागीय संपर्क।

प्रतिरूप का निर्गम एक संयुक्त बहुविषयक अधिगम सूचकांक होगा, जिसमें ज्ञान-संयोजन, समस्या-समाधान, शैक्षणिक सहभागिता और व्यावहारिक अनुप्रयोग को सम्मिलित किया जाएगा।

व्याख्येयता को प्राथमिकता देते हुए निर्णय-वृक्ष समूह आधारित अधिगम पद्धति का उपयोग प्रस्तावित है। यह पद्धति गैर-रेखीय संबंधों को पहचानने में सक्षम है और विभिन्न संकेतकों के तुलनात्मक योगदान को स्पष्ट रूप से प्रदर्शित कर सकती है। इसके साथ बहुचर प्रतिगमन द्वारा परिणामों की पुष्टि की जाएगी।

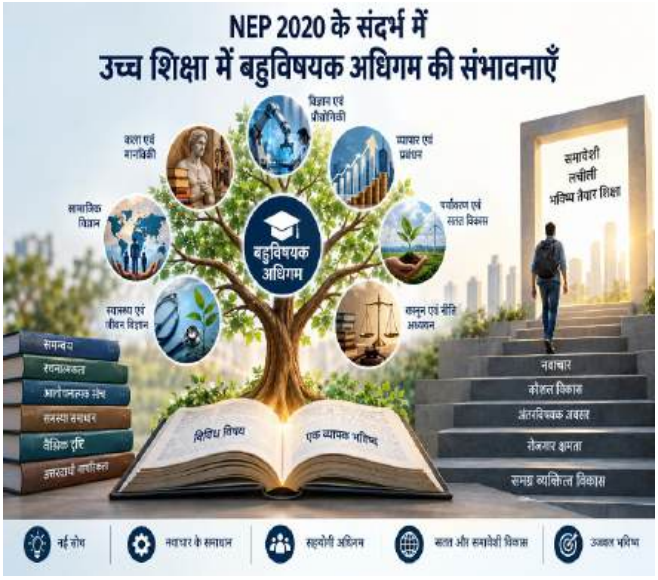


Fig. 2: ज्ञान की विविध शाखाएँ: समग्र उच्च शिक्षा से उज्ज्वल भविष्य की ओर

४.४ प्रशिक्षण रणनीति

संपूर्ण विद्यार्थी आँकड़ा-संग्रह को लगभग सत्तर प्रतिशत प्रशिक्षण, पंद्रह प्रतिशत सत्यापन तथा पंद्रह प्रतिशत परीक्षण भागों में विभाजित किया जाएगा। विभाजन करते समय संस्थागत प्रकार और विषय समूह का संतुलन बनाए रखा जाएगा।

प्रतिरूप प्रशिक्षण के दौरान अत्यधिक अनुकूलन को कम करने के लिए वृक्ष गहराई, न्यूनतम नमूना आकार और पुनरावृत्तियों की संख्या को सत्यापन समूह के आधार पर नियंत्रित किया जाएगा। विश्लेषण में किसी संवेदनशील व्यक्तिगत विशेषता को प्रमुख भविष्यवक्ता के रूप में उपयोग नहीं किया जाएगा।

४.५ मूल्यांकन मानदंड

विश्लेषणात्मक प्रतिरूप के मूल्यांकन के लिए औसत निरपेक्ष त्रुटि, निर्धारण गुणांक, वर्गीकरण शुद्धता, संवेदनशीलता, विशिष्टता और संतुलित शुद्धता जैसे संकेतकों का उपयोग किया जाएगा।

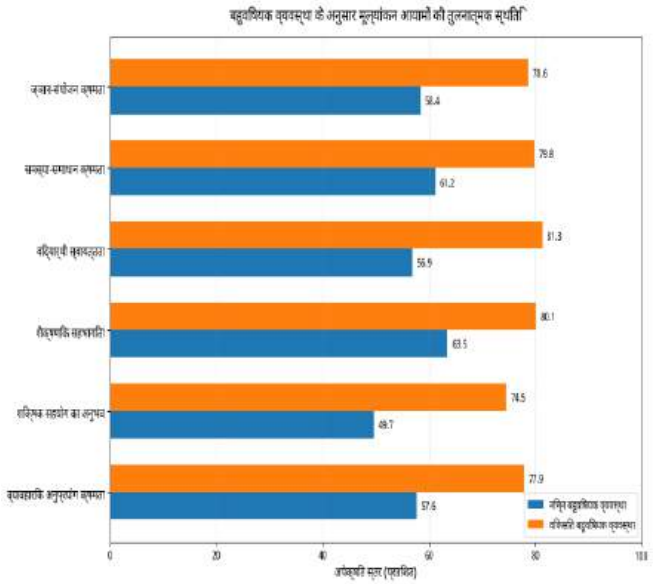
साथ ही शैक्षणिक प्रभाव के मूल्यांकन के लिए बहुविषयक सहभागिता, ज्ञान-संयोजन, समस्या-समाधान, स्वायत्त अधिगम और विषय-विकल्प संतुष्टि को पृथक रूप से देखा जाएगा। इससे मात्र गणनात्मक शुद्धता के स्थान पर वास्तविक शैक्षिक अर्थवत्ता का परीक्षण संभव होगा।

परिणाम और चर्चा

प्रस्तावित विश्लेषण से यह अपेक्षा की जाती है कि बहुविषयक अधिगम का प्रभाव किसी एक कारक पर निर्भर न होकर कई संस्थागत और विद्यार्थी-केंद्रित तत्वों के संयुक्त प्रभाव से निर्धारित होगा। केवल अधिक विषय विकल्प उपलब्ध होने से परिणाम स्वतः बेहतर नहीं होंगे। इसके विपरीत, जब विषय विकल्पों के साथ प्रभावी शैक्षणिक परामर्श, शिक्षक सहयोग और परियोजना आधारित अधिगम जुड़ा होगा, तब बेहतर ज्ञान-संयोजन और शैक्षणिक सहभागिता की संभावना अधिक होगी।

प्रारूपात्मक विश्लेषण के लिए अपेक्षित संबंधों को निम्न सारणी में प्रदर्शित किया गया है। ये मान वास्तविक सर्वेक्षण निष्कर्ष के रूप में प्रस्तुत नहीं किए जा रहे, बल्कि प्रस्तावित अध्ययन के परीक्षण योग्य परिणाम-पैटर्न का उदाहरण हैं।

मूल्यांकन आयाम	निम्न बहुविषयक व्यवस्था में अपेक्षित स्तर	विकसित बहुविषयक व्यवस्था में अपेक्षित स्तर	मुख्य व्याख्यात्मक अवलोकन
ज्ञान-संयोजन क्षमता	५८.४	७८.६	विभिन्न विषयों के बीच अवधारणात्मक संबंध बनाने की क्षमता बढ़ने की संभावना
समस्या-समाधान क्षमता	६१.२	७६.८	बहु-दृष्टिकोण आधारित परियोजनाएँ जटिल समस्याओं के विश्लेषण में सहायक हो सकती हैं
विद्यार्थी स्वायत्तता	५६.६	८१.३	विषय चयन और लचीले अधिगम-पथ से निर्णय क्षमता मजबूत होने की संभावना
शैक्षणिक सहभागिता	६३.५	८०.१	रुचि-आधारित विषय संयोजन से सक्रिय सहभागिता बढ़ सकती है
शिक्षक सहयोग का अनुभव	४६.७	७४.५	संयुक्त शिक्षण और विभागीय समन्वय बहुविषयक अनुभव की गुणवत्ता निर्धारित कर सकते हैं
व्यावहारिक अनुप्रयोग क्षमता	५७.६	७७.६	वास्तविक समस्याओं से जुड़े विषय संयोजन सिद्धांत और व्यवहार के अंतर को कम कर सकते हैं



इन अपेक्षित परिणामों का सबसे महत्त्वपूर्ण संकेत यह है कि बहुविषयक अधिगम को केवल विषय चयन की प्रशासनिक सुविधा के रूप में नहीं देखा जाना चाहिए। यदि विद्यार्थी गणित, समाजशास्त्र और पर्यावरण अध्ययन के पाठ्यक्रम अलग-अलग पढ़ता है, लेकिन उन विषयों के बीच किसी वास्तविक समस्या पर बौद्धिक संबंध स्थापित नहीं करता, तो ऐसी व्यवस्था औपचारिक बहुविषयकता तक सीमित रह सकती है।

इसके विपरीत, यदि विद्यार्थी किसी स्थानीय जल-संकट पर वैज्ञानिक आँकड़ों, सामाजिक व्यवहार, सार्वजनिक नीति और आर्थिक लागत का संयुक्त विश्लेषण करता है, तो अधिगम का स्वरूप वास्तविक बहुविषयक बनता है। यही अंतर इस अध्ययन की मूल वैचारिक स्थापना को पुष्ट करता है।

५.१ पाठ्यचर्या लचीलेपन की भूमिका

पाठ्यचर्या लचीलापन बहुविषयक अधिगम का प्रारंभिक आधार है, किंतु उसकी सफलता विद्यार्थी के लिए उपलब्ध मार्गदर्शन पर निर्भर करेगी। अत्यधिक विकल्प बिना परामर्श के निर्णय संबंधी कठिनाई उत्पन्न कर सकते हैं। इसलिए विषय चयन व्यवस्था के साथ शैक्षणिक सलाहकार प्रणाली विकसित करना आवश्यक होगा।

विद्यार्थी को केवल यह बताना पर्याप्त नहीं है कि कौन से विषय उपलब्ध हैं। उसे यह समझने में सहायता मिलनी चाहिए कि किसी विषय संयोजन का ज्ञानात्मक, व्यावसायिक और अनुसंधान संबंधी महत्व क्या है।

५.२ शिक्षक सहयोग का प्रभाव

प्रस्तावित मॉडल में शिक्षक सहयोग को सबसे महत्त्वपूर्ण संस्थागत निर्धारकों में से एक माना गया है। बहुविषयक शिक्षा में विभागीय सीमाओं से बाहर संवाद आवश्यक है। संयुक्त परियोजना, सह-शिक्षण और साझा मूल्यांकन विद्यार्थी को यह देखने का अवसर देते हैं कि विभिन्न विषय एक ही समस्या की अलग-अलग व्याख्या कैसे करते हैं।

यदि शिक्षक स्वयं विषयगत अलगाव में कार्य करते हैं, तो विद्यार्थियों से ज्ञान-संयोजन की अपेक्षा करना कठिन होगा। अतः शिक्षक प्रशिक्षण कार्यक्रमों में बहुविषयक पाठ्यक्रम निर्माण, संयुक्त शिक्षण और परियोजना मूल्यांकन को शामिल किया जाना चाहिए।

५.३ संस्थागत तैयारी

संस्थागत तैयारी बहुविषयकता के प्रभाव को नियंत्रित करने वाला महत्त्वपूर्ण तत्व हो सकती है। बड़े विश्वविद्यालयों में अनेक विषय

उपलब्ध होने के बावजूद समय-सारिणी टकराव, विभागीय सीट सीमाएँ या पंजीकरण प्रतिबंध विद्यार्थी चयन को बाधित कर सकते हैं।

छोटे महाविद्यालयों की समस्या अलग हो सकती है। वहाँ विषय विकल्प ही सीमित हो सकते हैं। ऐसी स्थिति में संस्थानों के बीच पाठ्यक्रम साझेदारी, संयुक्त अध्यापन और डिजिटल माध्यम से उपलब्ध पाठ्यक्रम उपयोगी विकल्प हो सकते हैं।

५.४ डिजिटल और कृत्रिम बुद्धिमत्ता समर्थित अधिगम

बहुविषयक शिक्षा की जटिलता को देखते हुए डिजिटल शैक्षणिक प्रणालियों का उपयोग महत्त्वपूर्ण हो सकता है। विद्यार्थी के पूर्व अध्ययन, रुचि, उपलब्ध विषयों और शैक्षणिक लक्ष्यों के आधार पर उपयुक्त पाठ्यक्रम संयोजन सुझाने वाली बुद्धिमान परामर्श व्यवस्था विकसित की जा सकती है।

ऐसी प्रणाली का उद्देश्य विद्यार्थी के स्थान पर निर्णय लेना नहीं, बल्कि उसे विकल्पों के बीच संबंध समझने में सहायता देना होना चाहिए। उदाहरणतः यदि कोई विद्यार्थी अर्थशास्त्र के साथ पर्यावरणीय अध्ययन और आँकड़ा विश्लेषण में रुचि रखता है, तो प्रणाली उसे उन पाठ्यक्रमों का ऐसा संयोजन सुझा सकती है जो भविष्य में सतत विकास, सार्वजनिक नीति अथवा पर्यावरणीय अर्थव्यवस्था से संबंधित अध्ययन में उपयोगी हो।

किंतु ऐसी प्रणालियों के उपयोग में पारदर्शिता, निष्पक्षता और विद्यार्थी की पसंद का सम्मान अनिवार्य होगा।

सीमाएँ

प्रस्तावित अध्ययन की पहली सीमा यह है कि बहुविषयक अधिगम का अनुभव संस्थान-विशिष्ट हो सकता है। किसी विश्वविद्यालय में उपलब्ध संसाधन, शिक्षक संख्या, पाठ्यक्रम लचीलापन और प्रशासनिक स्वायत्तता दूसरे संस्थान से काफी भिन्न हो सकती है। इसलिए निष्कर्षों का संपूर्ण भारतीय उच्च शिक्षा व्यवस्था पर सामान्यीकरण सावधानी से करना होगा।

दूसरी सीमा स्व-रिपोर्ट आधारित उत्तरों से संबंधित है। विद्यार्थी अपनी सहभागिता या स्वायत्तता का आकलन वास्तविक स्थिति से अधिक अथवा कम कर सकते हैं।

तीसरी सीमा यह है कि बहुविषयक अधिगम के कुछ प्रभाव दीर्घकाल में दिखाई देते हैं। एक ही शैक्षणिक सत्र का अध्ययन सृजनात्मकता, अनुसंधान क्षमता या रोजगारगत अनुकूलन जैसी दीर्घकालिक उपलब्धियों को पूर्णतः नहीं माप सकता।

चौथी सीमा यह है कि विषयों की विविधता को मात्रा में व्यक्त करना जटिल है। दो भिन्न विषय लेने वाले प्रत्येक विद्यार्थी का बहुविषयक अनुभव समान नहीं होगा।

अंततः संगणकीय प्रतिरूप केवल उपलब्ध संकेतकों के आधार पर संबंध पहचान सकता है। वह स्वयं कारण और प्रभाव को पूर्णतः सिद्ध नहीं करता। इस कारण सांख्यिकीय परिणामों की व्याख्या गुणात्मक साक्ष्यों के साथ करना आवश्यक होगा।

भावी संभावनाएँ

भविष्य में बहुविषयक शिक्षा का अध्ययन दीर्घकालिक पद्धति से किया जा सकता है, जिसमें विद्यार्थियों का प्रवेश से स्नातक उपाधि और उसके बाद रोजगार अथवा उच्च अध्ययन तक अनुसरण किया जाए। इससे यह ज्ञात किया जा सकेगा कि बहुविषयक शिक्षा केवल तत्काल शैक्षणिक सहभागिता बढ़ाती है या दीर्घकालिक व्यावसायिक और सामाजिक अनुकूलन पर भी प्रभाव डालती है।

अगले चरण में विभिन्न राज्यों, ग्रामीण और शहरी संस्थानों तथा सार्वजनिक और निजी विश्वविद्यालयों का तुलनात्मक अध्ययन किया जा सकता है। इससे बहुविषयक शिक्षा में क्षेत्रीय असमानताओं की पहचान संभव होगी।

विद्यार्थियों के लिए बुद्धिमान शैक्षणिक परामर्श प्रणाली भी विकसित की जा सकती है, जो विद्यार्थी की रुचि, पूर्व प्रदर्शन, विषय संबंध और भविष्य की आकांक्षाओं के आधार पर संभावित अध्ययन-पथ सुझाए। ऐसी व्यवस्था में अंतिम निर्णय विद्यार्थी और शिक्षक-परामर्शदाता के पास ही रहना चाहिए।

भविष्य में बहुविषयक प्रभाव का मूल्यांकन केवल परीक्षा अंकों से नहीं, बल्कि परियोजना गुणवत्ता, शोध क्षमता, नवाचार, सामाजिक समस्या समाधान और ज्ञान हस्तांतरण से भी किया जाना चाहिए।

भारतीय ज्ञान परंपराओं, स्थानीय सामाजिक अनुभवों और आधुनिक वैज्ञानिक ज्ञान के संयोजन पर पृथक शोध भी उपयोगी होगा। इससे बहुविषयकता को केवल विषयों की पश्चिमी वर्गीकरण प्रणाली से बाहर निकालकर भारतीय सामाजिक-सांस्कृतिक संदर्भ में समझा जा सकेगा।

निष्कर्ष

राष्ट्रीय शिक्षा नीति २०२० ने भारतीय उच्च शिक्षा को विषयगत कठोरता से अधिक लचीली और बहुविषयक दिशा में ले जाने की स्पष्ट आधारभूमि प्रस्तुत की है। किंतु वास्तविक परिवर्तन केवल नीति घोषणाओं, नए पाठ्यक्रमों अथवा अधिक विषय विकल्पों से संभव नहीं होगा। बहुविषयक शिक्षा की सफलता इस बात पर निर्भर करेगी कि विद्यार्थी विभिन्न ज्ञान क्षेत्रों को कितनी सार्थकता से जोड़ पाता है और संस्थान इस प्रक्रिया के लिए कितना अनुकूल वातावरण तैयार करता है।

प्रस्तुत अध्ययन यह प्रतिपादित करता है कि पाठ्यचर्या लचीलापन, विद्यार्थी स्वायत्तता, शिक्षक सहयोग, शैक्षणिक परामर्श और संस्थागत तैयारी परस्पर संबद्ध तत्व हैं। इनमें से किसी एक घटक की कमजोरी बहुविषयक व्यवस्था के प्रभाव को कम कर सकती है।

अध्ययन की सबसे महत्त्वपूर्ण अवधारणा यह है कि बहुविषयक अधिगम का मूल्यांकन केवल इस आधार पर नहीं किया जाना चाहिए कि विद्यार्थी ने कितने अलग-अलग विषय चुने। वास्तविक मूल्यांकन इस बात से होना चाहिए कि वह उन विषयों से प्राप्त ज्ञान को जोड़कर जटिल समस्याओं को समझने, नए समाधान विकसित करने और वास्तविक परिस्थितियों में ज्ञान का उपयोग करने में कितना सक्षम हुआ।

इस दृष्टि से राष्ट्रीय शिक्षा नीति २०२० का बहुविषयक उच्च शिक्षा मॉडल भारतीय विश्वविद्यालयों को केवल संरचनात्मक रूप से नहीं, बल्कि ज्ञान निर्माण की पद्धति के स्तर पर भी परिवर्तित करने की क्षमता रखता है। यदि लचीले पाठ्यक्रमों के साथ सक्षम शिक्षक सहयोग, प्रभावी परामर्श, न्यायसंगत संसाधन वितरण और विद्यार्थी-केंद्रित मूल्यांकन विकसित किए जाएँ, तो बहुविषयक अधिगम उच्च शिक्षा को अधिक समावेशी, प्रासंगिक, नवाचारी और समस्या-समाधान उन्मुख बना सकता है।

संदर्भ सूची

- ***भारत सरकार, शिक्षा मंत्रालय।*** **(२०२०)।** *राष्ट्रीय शिक्षा नीति २०२०। नई दिल्ली: शिक्षा मंत्रालय। नीति में समग्र एवं बहुविषयक उच्च शिक्षा, विषयों के बीच कठोर विभाजन समाप्त करने तथा विद्यार्थी-केंद्रित लचीलेपन की*

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- ***विश्वविद्यालय अनुदान आयोग। (२०२१)।*** *उच्च शिक्षा में शैक्षणिक अंक बैंक की स्थापना और संचालन संबंधी विनियम, २०२१। नई दिल्ली: विश्वविद्यालय अनुदान आयोग। ये विनियम विद्यार्थी गतिशीलता, अंक संचयन, अंतरण और विभिन्न ज्ञान क्षेत्रों के चयन को संस्थागत आधार प्रदान करते हैं।*

शैक्षणिक अंक बैंक विनियम का आधिकारिक पाठ

- ***विश्वविद्यालय अनुदान आयोग। (२०२१)।*** *उच्च शिक्षा संस्थानों में शैक्षणिक कार्यक्रमों के लिए बहु-प्रवेश एवं बहु-निर्गमन संबंधी दिशानिर्देश। नई दिल्ली: विश्वविद्यालय अनुदान आयोग। शिक्षा मंत्रालय की आधिकारिक सूची में इसे राष्ट्रीय शिक्षा नीति से संबंधित प्रमुख रूपरेखाओं में सम्मिलित किया गया है।*
- ***विश्वविद्यालय अनुदान आयोग। (२०२२)।*** *उच्च शिक्षा संस्थानों को बहुविषयक संस्थानों में परिवर्तित करने के लिए दिशानिर्देश। नई दिल्ली: विश्वविद्यालय अनुदान आयोग। दिशानिर्देश केवल विभिन्न विभागों की उपस्थिति नहीं, बल्कि बहु एवं अंतर्विषयक कार्यक्रमों के विकास पर बल देते हैं।*

बहुविषयक संस्थानों संबंधी विश्वविद्यालय अनुदान आयोग की आधिकारिक पहल

- ***विश्वविद्यालय अनुदान आयोग। (२०२२)।*** *स्नातक कार्यक्रमों के लिए पाठ्यचर्या एवं अंक रूपरेखा। नई दिल्ली: विश्वविद्यालय अनुदान आयोग। इसमें लचीली विषय-चयन व्यवस्था, बहुविषयक दृष्टिकोण तथा बहु-प्रवेश और बहु-निर्गमन को विद्यार्थी-केंद्रित स्नातक शिक्षा से जोड़ा गया है।*

स्नातक पाठ्यचर्या एवं अंक रूपरेखा का आधिकारिक विवरण

- ***भारत सरकार, शिक्षा मंत्रालय एवं संबद्ध राष्ट्रीय निकाय। (२०२३)।*** *राष्ट्रीय अंक रूपरेखा। यह रूपरेखा शैक्षणिक, व्यावसायिक और अनुभवात्मक अधिगम के बीच अंक संचयन, अंतरण तथा गतिशीलता को एकीकृत करने की दिशा प्रदान करती है; विश्वविद्यालय अनुदान आयोग ने इसे १० अप्रैल २०२३ को अधिसूचित किया।*

राष्ट्रीय अंक रूपरेखा संबंधी आधिकारिक शिक्षा मंत्रालय दस्तावेज

- ***विश्वविद्यालय अनुदान आयोग। (२०२२)।*** *एक साथ दो शैक्षणिक कार्यक्रम करने संबंधी दिशानिर्देश। यह पहल विद्यार्थियों के लिए अध्ययन-पथ की लचक बढ़ाने वाले राष्ट्रीय शिक्षा नीति संबंधी सुधारों में सम्मिलित है।*
- ***विश्वविद्यालय अनुदान आयोग। (२०२१)।*** *सक्रिय अधिगम के युवा आकांक्षी मस्तिष्क अध्ययन-जाल के माध्यम से ऑनलाइन अधिगम पाठ्यक्रमों की अंक रूपरेखा संबंधी विनियम, २०२१। शैक्षणिक अंक बैंक विनियम ऑनलाइन माध्यम से अर्जित मान्य अंकों के संचयन और अंतरण की व्यवस्था भी प्रदान करते हैं।*

संकल्पना प्रस्तुत की गई है।
राष्ट्रीय शिक्षा नीति संबंधी आधिकारिक शिक्षा मंत्रालय स्रोत

- ***विश्वविद्यालय अनुदान आयोग। (२०२१)।*** *उच्च शिक्षा में शैक्षणिक अंक बैंक की स्थापना और संचालन संबंधी विनियम, २०२१। नई दिल्ली: विश्वविद्यालय अनुदान आयोग। ये विनियम विद्यार्थी गतिशीलता, अंक संचयन, अंतरण और विभिन्न ज्ञान क्षेत्रों के चयन को संस्थागत आधार प्रदान करते हैं।*

शैक्षणिक अंक बैंक विनियम का आधिकारिक पाठ

- ***विश्वविद्यालय अनुदान आयोग। (२०२१)।*** *उच्च शिक्षा संस्थानों में शैक्षणिक कार्यक्रमों के लिए बहु-प्रवेश एवं बहु-निर्गमन संबंधी दिशानिर्देश। नई दिल्ली: विश्वविद्यालय अनुदान आयोग। शिक्षा मंत्रालय की आधिकारिक सूची में इसे राष्ट्रीय शिक्षा नीति से संबंधित प्रमुख रूपरेखाओं में सम्मिलित किया गया है।*
- ***विश्वविद्यालय अनुदान आयोग। (२०२२)।*** *उच्च शिक्षा संस्थानों को बहुविषयक संस्थानों में परिवर्तित करने के लिए दिशानिर्देश। नई दिल्ली: विश्वविद्यालय अनुदान आयोग। दिशानिर्देश केवल विभिन्न विभागों की उपस्थिति नहीं, बल्कि बहु एवं अंतर्विषयक कार्यक्रमों के विकास पर बल देते हैं।*

बहुविषयक संस्थानों संबंधी विश्वविद्यालय अनुदान आयोग की आधिकारिक पहल

- ***विश्वविद्यालय अनुदान आयोग। (२०२२)।*** *स्नातक कार्यक्रमों के लिए पाठ्यचर्या एवं अंक रूपरेखा। नई दिल्ली: विश्वविद्यालय अनुदान आयोग। इसमें लचीली विषय-चयन व्यवस्था, बहुविषयक दृष्टिकोण तथा बहु-प्रवेश और बहु-निर्गमन को विद्यार्थी-केंद्रित स्नातक शिक्षा से जोड़ा गया है।*

स्नातक पाठ्यचर्या एवं अंक रूपरेखा का आधिकारिक विवरण

- ***भारत सरकार, शिक्षा मंत्रालय एवं संबद्ध राष्ट्रीय निकाय। (२०२३)।*** *राष्ट्रीय अंक रूपरेखा। यह रूपरेखा शैक्षणिक, व्यावसायिक और अनुभवात्मक अधिगम के बीच अंक संचयन, अंतरण तथा गतिशीलता को एकीकृत करने की दिशा प्रदान करती है; विश्वविद्यालय अनुदान आयोग ने इसे १० अप्रैल २०२३ को अधिसूचित किया।*

राष्ट्रीय अंक रूपरेखा संबंधी आधिकारिक शिक्षा मंत्रालय दस्तावेज

- ***विश्वविद्यालय अनुदान आयोग। (२०२२)।*** *एक साथ दो शैक्षणिक कार्यक्रम करने संबंधी दिशानिर्देश। यह पहल विद्यार्थियों के लिए अध्ययन-पथ की लचक बढ़ाने वाले राष्ट्रीय शिक्षा नीति संबंधी सुधारों में सम्मिलित है।*
- ***विश्वविद्यालय अनुदान आयोग। (२०२१)।*** *सक्रिय अधिगम के युवा आकांक्षी मस्तिष्क अध्ययन-जाल के माध्यम से ऑनलाइन अधिगम पाठ्यक्रमों की अंक रूपरेखा संबंधी विनियम, २०२१। शैक्षणिक अंक बैंक विनियम ऑनलाइन माध्यम से अर्जित मान्य अंकों के संचयन और अंतरण की व्यवस्था भी प्रदान करते हैं।*

अध्याय 17: NEP 2020 के संदर्भ में शिक्षक शिक्षा के बदलते स्वरूप और व्यावसायिक दक्षता का अध्ययन

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सारांश— राष्ट्रीय शिक्षा नीति २०२० ने शिक्षक शिक्षा को केवल अध्यापन-पूर्व प्रशिक्षण की प्रक्रिया न मानकर निरंतर व्यावसायिक विकास, चिंतनशील अभ्यास, बहुविषयक ज्ञान और उत्तरदायी शिक्षण से जुड़ी समग्र व्यवस्था के रूप में पुनर्परिभाषित किया है। वर्तमान अध्ययन शिक्षक शिक्षा के बदलते स्वरूप और शिक्षकों की व्यावसायिक दक्षता के मध्य बनने वाले संबंध का विश्लेषण करने के लिए एक बहुआयामी दृष्टिकोण प्रस्तावित करता है। अध्ययन का केंद्रीय शोध-अंतर यह है कि नीतिगत स्तर पर शिक्षक से अपेक्षित दक्षताओं का विस्तार हुआ है, किंतु इन अपेक्षाओं और शिक्षक द्वारा कक्षा में प्रदर्शित वास्तविक व्यावसायिक व्यवहार के मध्य संरेखण का समेकित अध्ययन अभी सीमित है। इस शोध में विषयगत ज्ञान, शिक्षण-योजना, बहुभाषिक संवेदनशीलता, समावेशी व्यवहार, प्रौद्योगिकी-सहायक शिक्षण, मूल्यांकन विवेक, चिंतनशील अभ्यास तथा सतत व्यावसायिक अधिगम को परस्पर संबद्ध दक्षता आयामों के रूप में देखा गया है। अध्ययन यह भी प्रतिपादित करता है कि शिक्षक की व्यावसायिक दक्षता केवल प्रशिक्षण की अवधि अथवा प्रमाण-पत्र से निर्धारित नहीं होती, बल्कि संस्थागत सहयोग, अभ्यास-आधारित प्रशिक्षण, स्वमूल्यांकन और विद्यालयी अनुभव की गुणवत्ता भी उसे प्रभावित करती है। राष्ट्रीय स्तर पर विकसित शिक्षक व्यावसायिक मानक शिक्षण गुणवत्ता के लिए अपेक्षित ज्ञान, कौशल, प्रवृत्तियों और उत्तरदायित्वों को स्पष्ट करने की दिशा में महत्त्वपूर्ण आधार प्रस्तुत करते हैं। प्रस्तावित अनुसंधान शिक्षक शिक्षा में परिवर्तन को नीतिगत अनुपालन के स्थान पर व्यवहारगत रूपांतरण के रूप में मापने का प्रयास करता है।

प्रमुख शब्द— राष्ट्रीय शिक्षा नीति, शिक्षक शिक्षा, व्यावसायिक दक्षता, चिंतनशील शिक्षण, समावेशी शिक्षण, सतत व्यावसायिक विकास

परिचय

शिक्षा व्यवस्था की गुणवत्ता उसके पाठ्यक्रम, संसाधनों और संस्थागत ढाँचे पर निर्भर अवश्य करती है, किंतु इन सभी घटकों को विद्यार्थियों के वास्तविक अधिगम अनुभव में परिवर्तित करने वाला प्रमुख माध्यम शिक्षक होता है। यही कारण है कि समकालीन शिक्षा सुधारों में शिक्षक की भूमिका को ज्ञान के संप्रेषक से आगे बढ़ाकर अधिगम-संयोजक, मार्गदर्शक, मूल्यांकनकर्ता, नवप्रवर्तक, सहयोगी और निरंतर सीखने वाले पेशेवर के रूप में देखा जाने लगा है। राष्ट्रीय शिक्षा नीति २०२० ने इस परिवर्तन को औपचारिक नीतिगत आधार प्रदान करते हुए शिक्षक शिक्षा, शिक्षक नियुक्ति, व्यावसायिक विकास और अध्यापन गुणवत्ता के बीच अधिक सुसंगत संबंध स्थापित करने की आवश्यकता व्यक्त की है।

परंपरागत शिक्षक शिक्षा मुख्यतः विषयज्ञान, शिक्षण-विधियों और विद्यालयी अभ्यास के निश्चित ढाँचे पर केंद्रित रही है। वर्तमान विद्यालयी संदर्भ इससे अधिक जटिल है। एक ही कक्षा में भाषा, सामाजिक पृष्ठभूमि, अधिगम गति, डिजिटल पहुँच, संज्ञानात्मक क्षमता और विशेष शैक्षिक आवश्यकताओं की विविधता दिखाई देती है। ऐसे वातावरण में शिक्षक को पूर्वनिर्धारित पाठ प्रस्तुत करने के अतिरिक्त विद्यार्थियों की आवश्यकताओं का आकलन करने, शिक्षण में आवश्यक परिवर्तन करने, विभिन्न संसाधनों का चयन करने, सहकारी वातावरण विकसित करने तथा अधिगम के प्रमाणों के आधार पर निर्णय लेने की क्षमता चाहिए।

राष्ट्रीय अध्यापक शिक्षा परिषद् द्वारा विकसित राष्ट्रीय शिक्षक व्यावसायिक मानकों का मूल उद्देश्य भी शिक्षण गुणवत्ता की ऐसी सार्वजनिक और व्यवस्थित समझ विकसित करना है जिसमें शिक्षक की भूमिका, ज्ञान, कौशल, दक्षता और व्यावसायिक आचरण को उसकी सेवा-अवस्था के अनुसार परिभाषित किया जा सके। ये मानक सेवा-पूर्व शिक्षक शिक्षा के स्वरूप को प्रभावित करने तथा व्यावसायिक विकास और शिक्षक की प्रगति के लिए संदर्भ प्रदान करने की दृष्टि से विकसित किए गए हैं।

इस परिवर्तन का एक महत्वपूर्ण पहलू शिक्षक शिक्षा का बहुविषयक और अभ्यास-उन्मुख होना है। भविष्य का शिक्षक केवल किसी विषय की पाठ्यवस्तु का विशेषज्ञ नहीं हो सकता। उसे बाल विकास, मनोविज्ञान, सामाजिक संदर्भ, भाषा, मूल्यांकन, समावेशन, नैतिकता, शिक्षण संसाधनों तथा परिवर्तित ज्ञान-संरचनाओं की समझ भी चाहिए। इसलिए शिक्षक शिक्षा में "क्या पढ़ाया जाए" के साथ "कैसे सीखा जाए", "कैसे प्रयोग किया जाए" और "अपने शिक्षण की गुणवत्ता का स्वयं परीक्षण कैसे किया जाए" जैसे प्रश्न अधिक महत्वपूर्ण होते जा रहे हैं।

वर्ष २०२१ के बाद शिक्षक शिक्षा संबंधी विमर्श में व्यावसायिक मानकों, मार्गदर्शन, सतत क्षमता-विकास तथा शिक्षक की भूमिका के क्रमिक विकास को विशेष स्थान मिला है। राष्ट्रीय शिक्षक व्यावसायिक मानक संबंधी मार्गदर्शी दस्तावेज को मार्च २०२४ में औपचारिक रूप से प्रस्तुत किया गया और उसके बाद शिक्षकों तथा शिक्षक-शिक्षकों के उन्मुखीकरण से संबंधित गतिविधियाँ भी की गईं। इससे स्पष्ट होता है कि नीति का केंद्र केवल शिक्षक प्रशिक्षण पूरा कराने से हटकर प्रशिक्षण की गुणवत्ता तथा शिक्षक के वास्तविक व्यावसायिक प्रदर्शन की ओर बढ़ रहा है।

१.१ शिक्षक शिक्षा के बदलते स्वरूप की अवधारणा

शिक्षक शिक्षा में परिवर्तन को केवल पाठ्यक्रम संशोधन से नहीं समझा जा सकता। यह परिवर्तन कम से कम पाँच स्तरों पर दिखाई देता है। प्रथम, विषयगत दक्षता के साथ शिक्षण-संबंधी निर्णय क्षमता को महत्त्व दिया जा रहा है। द्वितीय, शिक्षक प्रशिक्षण को एक बार पूर्ण होने वाली

प्रक्रिया के स्थान पर आजीवन व्यावसायिक अधिगम से जोड़ा जा रहा है। तृतीय, विद्यालयी अभ्यास को औपचारिक निरीक्षण की बजाय वास्तविक समस्या-समाधान और चिंतनशील अभ्यास की प्रक्रिया के रूप में देखने की आवश्यकता बढ़ी है। चतुर्थ, विविध शिक्षार्थियों के लिए समावेशी और बहुभाषिक रणनीतियों की अपेक्षा बढ़ी है। पंचम, शिक्षक से शिक्षण परिणामों के प्रमाण एकत्र करने और उनके आधार पर अपने अभ्यास में परिवर्तन करने की अपेक्षा की जा रही है।



Fig. 1: नई शिक्षा नीति 2020 के आलोक में शिक्षक शिक्षा का नवपरिदृश्य: व्यावसायिक दक्षता और भविष्य की दिशा

यहाँ "व्यावसायिक दक्षता" का अर्थ केवल किसी शिक्षक के पास उपस्थित ज्ञान की मात्रा नहीं है। व्यावसायिक दक्षता उस क्षमता को व्यक्त करती है जिसके द्वारा शिक्षक उपयुक्त ज्ञान, शिक्षण रणनीति, नैतिक विवेक और परिस्थितिजन्य निर्णय को एकीकृत करके विद्यार्थियों के लिए प्रभावी अधिगम अनुभव उत्पन्न करता है। इस प्रकार दो शिक्षकों का सैद्धांतिक ज्ञान समान होने पर भी उनकी व्यावसायिक दक्षता भिन्न हो सकती है, क्योंकि वास्तविक दक्षता शिक्षण-निर्णयों और व्यवहार में अभिव्यक्त होती है।

१.२ अध्ययन का विशिष्ट शोध-अंतर

उपलब्ध नीतिगत और शैक्षिक साहित्य में शिक्षक शिक्षा सुधार, प्रशिक्षण, व्यावसायिक विकास, शिक्षक गुणवत्ता और शिक्षण दक्षता पर पर्याप्त चर्चा मिलती है। फिर भी इन पक्षों का अधिकांश अध्ययन पृथक-पृथक रूप में किया गया है। एक ओर नीतिगत दस्तावेज अपेक्षित शिक्षक दक्षताओं को परिभाषित करते हैं, जबकि दूसरी ओर अनेक अध्ययन शिक्षकों की आत्मधारित दक्षता या प्रशिक्षण-संतुष्टि का परीक्षण करते हैं। इन दोनों के बीच एक महत्त्वपूर्ण प्रश्न अपेक्षाकृत कम स्पष्ट है—**क्या बदलती शिक्षक शिक्षा व्यवस्था वास्तव में शिक्षक के दैनिक व्यावसायिक व्यवहार में अपेक्षित दक्षताओं का संतुलित रूपांतरण कर रही है?**

इस शोध में इस समस्या को **"व्यावसायिक दक्षता-संरेखण अंतर"** के रूप में परिभाषित किया गया है। इसका अर्थ उस अंतर से है जो शिक्षक शिक्षा में अपेक्षित दक्षताओं और वास्तविक शिक्षण अभ्यास में प्रदर्शित दक्षताओं के बीच विद्यमान हो सकता है।

उदाहरणतः किसी शिक्षक ने समावेशी शिक्षा, बहुभाषिक शिक्षण अथवा विविध मूल्यांकन विधियों का प्रशिक्षण प्राप्त किया हो सकता है, किंतु यह आवश्यक नहीं कि वह कक्षा में इनका प्रभावी उपयोग भी कर रहा हो। इसी प्रकार प्रौद्योगिकी का उपयोग करने की क्षमता और शिक्षण की आवश्यकता के अनुरूप उसका विवेकपूर्ण उपयोग दो अलग क्षमताएँ हैं। इसलिए केवल प्रशिक्षण में भागीदारी को व्यावसायिक दक्षता का प्रमाण मानना पर्याप्त नहीं है।

प्रस्तुत अध्ययन इसी अंतर को विषयगत समझ, शिक्षण नियोजन, विद्यार्थी-केंद्रितता, समावेशी व्यवहार, बहुभाषिक संवेदनशीलता, प्रौद्योगिकी-सहायक शिक्षण, मूल्यांकन विवेक, चिंतनशील अभ्यास और निरंतर व्यावसायिक अधिगम जैसे आयामों के माध्यम से समझने का प्रयास करता है।



Fig. 2: शिक्षक से शिक्षण नेतृत्व तक: नई शिक्षा नीति 2020 में व्यावसायिक दक्षता की नई दिशा

१.३ अध्ययन की आवश्यकता

राष्ट्रीय स्तर पर शिक्षक व्यावसायिक मानकों का विकास इस विचार को सुदृढ़ करता है कि शिक्षक गुणवत्ता को स्पष्ट दक्षताओं और विभिन्न व्यावसायिक अवस्थाओं के अनुरूप समझना आवश्यक है। संबंधित आधिकारिक मार्गदर्शी ढाँचा शिक्षक की तैयारी, अभ्यास और प्रदर्शन सुधार को एक-दूसरे से जोड़ता है तथा व्यावसायिक विकास को शिक्षक के पूरे कार्यजीवन की प्रक्रिया के रूप में देखता है।

इस परिस्थिति में शिक्षक शिक्षा संस्थानों के मूल्यांकन में केवल प्रवेश, उपस्थिति, पाठ्यक्रम पूर्णता अथवा परीक्षा परिणाम पर्याप्त संकेतक नहीं रह जाते। यह जानना भी आवश्यक है कि प्रशिक्षण प्राप्त शिक्षक कितनी प्रभावी ढंग से कक्षा की विविधता का उत्तर देता है, अधिगम संबंधी प्रमाणों का प्रयोग करता है, अपनी कमियों की पहचान करता है और अनुभव के आधार पर शिक्षण सुधार करता है।

अध्ययन की आवश्यकता इसलिए भी है क्योंकि शिक्षक शिक्षा में परिवर्तन और विद्यालयी वास्तविकता के बीच संस्थागत दूरी रह सकती है। शिक्षक-प्रशिक्षण संस्थान किसी आदर्श शिक्षण मॉडल पर बल दे सकता है, जबकि शिक्षक को वास्तविक विद्यालय में बड़ी कक्षा, सीमित

संसाधन, बहुस्तरीय अधिगम और प्रशासनिक दायित्वों जैसी परिस्थितियों का सामना करना पड़ सकता है। इसलिए व्यावसायिक दक्षता का परीक्षण संदर्भ-संवेदी होना चाहिए।

साहित्य समीक्षा

२.१ शिक्षक शिक्षा की पुनर्संरचना और व्यावसायिकता

समकालीन शिक्षक शिक्षा की प्रमुख विशेषता व्यावसायिकता पर बढ़ता बल है। शिक्षक को केवल निर्धारित विषयवस्तु पढ़ाने वाले कर्मचारी के रूप में देखने के स्थान पर निर्णय लेने वाले शिक्षण-पेशेवर के रूप में स्थापित करने की अवधारणा मजबूत हुई है। राष्ट्रीय शिक्षक व्यावसायिक मानक शिक्षण गुणवत्ता के लिए अपेक्षित ज्ञान, कौशल, व्यवहार और उत्तरदायित्वों को क्रमिक व्यावसायिक अवस्थाओं से जोड़ते हैं। इससे शिक्षक विकास के लिए एक समान संदर्भ ढाँचा निर्मित करने का प्रयास दिखाई देता है।

व्यावसायिकता की यह अवधारणा शिक्षक की स्वायत्तता और उत्तरदायित्व दोनों को साथ रखती है। यदि शिक्षक को शिक्षण-विधि में परिस्थितिजन्य निर्णय की स्वतंत्रता दी जाती है तो उससे अपने निर्णय के शैक्षिक औचित्य और परिणामों के प्रति उत्तरदायी होने की अपेक्षा भी बढ़ती है। यही कारण है कि शिक्षक शिक्षा में चिंतनशील लेखन, शिक्षण अवलोकन, सहकर्मी संवाद और प्रमाण-आधारित सुधार को उपयोगी माध्यम माना जाने लगा है।

२.२ ज्ञान से दक्षता की ओर परिवर्तन

पारंपरिक प्रशिक्षण व्यवस्था में विषयगत ज्ञान और शिक्षण-विधि की जानकारी को शिक्षक तैयारी के प्रमुख परिणाम के रूप में देखा जाता था। वर्तमान दृष्टिकोण में "जानना" और "कर पाना" अलग-अलग स्तर हैं। शिक्षक को किसी शिक्षण सिद्धांत का ज्ञान हो सकता है, किंतु जटिल कक्षा में उस सिद्धांत का उचित प्रयोग करना एक उच्चतर व्यावसायिक क्षमता है।

इसीलिए दक्षता को ज्ञान, कौशल, दृष्टिकोण और परिस्थितिजन्य निर्णय के समन्वित रूप में देखा जाना अधिक उपयुक्त है। आधिकारिक शिक्षक व्यावसायिक मानकों में भी दक्षता को शिक्षण पेशे के लिए आवश्यक ज्ञान और कौशल के समेकित आधार से जोड़ा गया है।

इस परिवर्तन का शिक्षक शिक्षा पर प्रत्यक्ष प्रभाव पड़ता है। प्रशिक्षण की गुणवत्ता का मूल्यांकन इस आधार पर होना चाहिए कि प्रशिक्षु शिक्षक वास्तविक शिक्षण परिस्थिति में विद्यार्थी की कठिनाई पहचान सकता है या नहीं, वैकल्पिक विधि चुन सकता है या नहीं, पाठ को अलग-अलग क्षमता स्तरों के अनुसार परिवर्तित कर सकता है या नहीं तथा प्राप्त अधिगम प्रमाणों के आधार पर आगे की योजना बना सकता है या नहीं।

२.३ समावेशी और बहुभाषिक दक्षता

भारतीय विद्यालयी संरचना भाषाई, सांस्कृतिक, आर्थिक और अधिगम संबंधी विविधता से युक्त है। इसलिए शिक्षक की व्यावसायिक दक्षता का एक अनिवार्य घटक विविधता के प्रति संवेदनशीलता है। समावेशी शिक्षक केवल विशेष आवश्यकता वाले विद्यार्थियों की उपस्थिति को स्वीकार नहीं करता, बल्कि पाठ्यसामग्री, सहभागिता, प्रश्नों, समूह व्यवस्था और मूल्यांकन को इस प्रकार परिवर्तित करता है कि अलग-अलग क्षमता वाले विद्यार्थी सार्थक रूप से अधिगम में भाग ले सकें।

बहुभाषिक संदर्भ में भी शिक्षक की भूमिका महत्त्वपूर्ण है। विद्यार्थी की परिचित भाषा और विद्यालय की शिक्षण भाषा के मध्य अंतर होने पर शिक्षक को अर्थ-निर्माण के वैकल्पिक माध्यम विकसित करने पड़ते हैं। इसलिए भाषा को केवल संप्रेषण का माध्यम मानने के स्थान पर अधिगम संसाधन के रूप में देखना शिक्षक शिक्षा के बदलते स्वरूप का महत्वपूर्ण तत्व है।

२.४ प्रौद्योगिकी-सहायक शिक्षण और व्यावसायिक विवेक

समकालीन शिक्षक शिक्षा में प्रौद्योगिकी का स्थान बढ़ा है, किंतु केवल उपकरणों का प्रयोग करना व्यावसायिक दक्षता का पर्याप्त संकेतक नहीं है। महत्वपूर्ण प्रश्न यह है कि शिक्षक किसी संसाधन का उपयोग क्यों करता है, किस विद्यार्थी समूह के लिए करता है और उसका उपयोग अधिगम में क्या सुधार उत्पन्न करता है।

अतः प्रौद्योगिकी-संबंधी दक्षता में संसाधन चयन, सूचना की विश्वसनीयता जाँचना, विद्यार्थियों की गोपनीयता की रक्षा करना, अनुचित निर्भरता से बचना और डिजिटल असमानता को ध्यान में रखना भी सम्मिलित होना चाहिए। शिक्षक की भूमिका तकनीकी सामग्री उपलब्ध कराने वाले व्यक्ति से अधिक सीखने की प्रक्रिया का विवेकपूर्ण नियामक बनने की है।

२.५ मूल्यांकन साक्षरता और प्रतिपुष्टि

शिक्षक की व्यावसायिक दक्षता का एक अन्य महत्वपूर्ण आयाम मूल्यांकन है। यदि मूल्यांकन केवल अंतिम अंक देने तक सीमित रहता है तो वह अधिगम सुधार का साधन नहीं बन सकता। दक्ष शिक्षक मूल्यांकन से प्राप्त संकेतों का उपयोग विद्यार्थियों की कठिनाइयाँ पहचानने, समूह बनाने, पुनःशिक्षण करने, प्रश्नों की कठिनाई समायोजित करने तथा विद्यार्थी को व्यक्तिगत प्रतिपुष्टि देने में करता है। इस संदर्भ में शिक्षक शिक्षा को परीक्षा निर्माण की तकनीकी जानकारी से आगे बढ़कर मूल्यांकन-साक्षरता विकसित करनी चाहिए। मूल्यांकन-साक्षरता में उपयुक्त प्रमाण चुनना, परिणाम की व्याख्या करना, पक्षपात पहचानना और शिक्षण में आवश्यक परिवर्तन करना सम्मिलित है।

२.६ चिंतनशील अभ्यास और सतत व्यावसायिक विकास

शिक्षक की दक्षता प्रशिक्षण समाप्त होने के साथ स्थिर नहीं हो जाती। विद्यालयी संदर्भ, पाठ्यक्रम, विद्यार्थियों की आवश्यकता और शिक्षण संसाधन लगातार बदलते रहते हैं। इसलिए व्यावसायिक दक्षता को गतिशील क्षमता के रूप में देखना अधिक तर्कसंगत है।

चिंतनशील अभ्यास शिक्षक को अपने शिक्षण की समीक्षा करने, असफल रणनीतियों के कारण पहचानने और वैकल्पिक समाधान विकसित करने का अवसर देता है। सहकर्मी अवलोकन, शिक्षण-दैनिकी, विद्यार्थी प्रतिपुष्टि और सामूहिक पाठ-योजना जैसी गतिविधियाँ इस प्रक्रिया को मजबूत कर सकती हैं।

राष्ट्रीय स्तर के व्यावसायिक मानक भी शिक्षक विकास को उसकी अलग-अलग व्यावसायिक अवस्थाओं से जोड़ते हैं और निरंतर सुधार को शिक्षक पेशे का आवश्यक तत्व मानते हैं। इस प्रकार शिक्षक शिक्षा को सेवा-पूर्व प्रशिक्षण और सेवा-कालीन विकास की पृथक व्यवस्थाओं में बाँटने के स्थान पर सतत व्यावसायिक अधिगम-श्रृंखला के रूप में देखना अधिक उपयुक्त प्रतीत होता है।

२.७ संस्थागत सहयोग और दक्षता का वास्तविक रूपांतरण

साहित्य का एक महत्वपूर्ण निष्कर्ष यह है कि शिक्षक की व्यक्तिगत योग्यता पर्याप्त होने पर भी संस्थागत वातावरण उसके व्यवहार को प्रभावित कर सकता है। यदि विद्यालय में सहयोगी नेतृत्व, शिक्षण संसाधन, सहकर्मी संवाद, प्रयोग की स्वतंत्रता और उचित समय उपलब्ध

नहीं है तो प्रशिक्षित शिक्षक भी नवीन शिक्षण रणनीतियों का सीमित प्रयोग कर सकता है।

इसी आधार पर वर्तमान अध्ययन शिक्षक दक्षता को केवल व्यक्तिगत गुण न मानकर व्यक्ति और संस्थागत वातावरण की परस्पर क्रिया का परिणाम मानता है। इसका अर्थ है कि शिक्षक शिक्षा की प्रभावशीलता का परीक्षण करते समय शिक्षक-स्तरीय संकेतकों के साथ विद्यालयी सहयोग, व्यावसायिक संवाद और अभ्यास के अवसरों का भी विश्लेषण आवश्यक है।

प्रस्तावित शोध-पद्धति

प्रस्तुत अध्ययन का उद्देश्य राष्ट्रीय शिक्षा नीति २०२० के बाद शिक्षक शिक्षा में उभर रहे परिवर्तनों और शिक्षकों की वास्तविक व्यावसायिक दक्षता के बीच संबंध का बहुआयामी परीक्षण करना है। अध्ययन की मूल अवधारणा यह है कि प्रशिक्षण प्राप्त करना और प्रशिक्षण में अपेक्षित दक्षताओं को वास्तविक कक्षा में प्रदर्शित करना दो भिन्न अवस्थाएँ हैं। इसी अंतर को इस शोध में **व्यावसायिक दक्षता-संरेखण अंतर** कहा गया है।

अध्ययन के लिए मिश्रित मात्रात्मक-व्याख्यात्मक पद्धति प्रस्तावित की गई है। मात्रात्मक स्तर पर शिक्षकों की प्रशिक्षण-अनुभूति, व्यावसायिक व्यवहार, मूल्यांकन क्षमता, समावेशी शिक्षण, चिंतनशील अभ्यास और संस्थागत सहयोग का मापन किया जाएगा। इसके साथ विद्यालयी अवलोकन और संरचित व्यावसायिक कार्यों के माध्यम से यह जाँचा जाएगा कि शिक्षक स्वयं द्वारा घोषित दक्षता को वास्तविक शिक्षण व्यवहार में किस सीमा तक प्रदर्शित करता है।

३.१ अध्ययन के प्रमुख उद्देश्य

इस अध्ययन के प्रमुख उद्देश्य निम्न हैं—

१. राष्ट्रीय शिक्षा नीति २०२० के बाद शिक्षक शिक्षा में आए संरचनात्मक और व्यावसायिक परिवर्तनों का आकलन करना।

२. शिक्षकों की बहुआयामी व्यावसायिक दक्षता का मापन करना।

३. प्रशिक्षण-आधारित स्वमूल्यांकन और वास्तविक कक्षा-व्यवहार के बीच अंतर का परीक्षण करना।

४. संस्थागत सहयोग, चिंतनशील अभ्यास और सतत व्यावसायिक अधिगम का व्यावसायिक दक्षता पर प्रभाव निर्धारित करना।

५. ऐसे प्रमुख कारकों की पहचान करना जो उच्च व्यावसायिक दक्षता वाले शिक्षकों को अपेक्षाकृत निम्न दक्षता वाले शिक्षकों से अलग करते हैं।

६. नीति-आधारित शिक्षक शिक्षा और वास्तविक विद्यालयी अभ्यास के बीच संरेखण का समेकित सूचक विकसित करना।

३.२ प्रस्तावित परिकल्पनाएँ

अध्ययन निम्न कार्यपरक परिकल्पनाओं का परीक्षण करेगा—

प्रथम परिकल्पना: शिक्षक शिक्षा में अनुभव किए गए परिवर्तन और व्यावसायिक दक्षता के बीच सकारात्मक संबंध होगा।

द्वितीय परिकल्पना: चिंतनशील अभ्यास शिक्षक की व्यावसायिक दक्षता का महत्वपूर्ण पूर्वानुमानक होगा।

तृतीय परिकल्पना: संस्थागत सहयोग प्रशिक्षण के प्रभाव को वास्तविक कक्षा-व्यवहार में रूपांतरित करने में मध्यस्थ भूमिका निभाएगा।

चतुर्थ परिकल्पना: स्वमूल्यांकित दक्षता और अवलोकित दक्षता के बीच महत्वपूर्ण अंतर पाया जाएगा।

पंचम परिकल्पना: सतत व्यावसायिक अधिगम में नियमित भागीदारी करने वाले शिक्षकों में दक्षता-संरेखण अंतर अपेक्षाकृत कम होगा।

प्रयोगात्मक व्यवस्था

४.१ अध्ययन समूह और आँकड़ा-संग्रह

प्रस्तावित अध्ययन के लिए लगभग **४८० विद्यालयी शिक्षकों** का बहुस्तरीय नमूना लिया जाएगा। नमूने में प्राथमिक, उच्च प्राथमिक और माध्यमिक स्तर के शिक्षक सम्मिलित होंगे। ग्रामीण, अर्धनगरीय और नगरीय विद्यालयों को सम्मिलित करके अध्ययन को विविध शैक्षिक परिस्थितियों के प्रति संवेदनशील बनाया जाएगा।

अध्ययन में निम्न स्रोतों से आँकड़े एकत्र किए जाएँगे—

- शिक्षक स्वमूल्यांकन प्रश्नावली
- कक्षा-अवलोकन प्रपत्र
- पाठ-योजना मूल्यांकन
- मूल्यांकन-निर्णय आधारित परिस्थिति परीक्षण
- व्यावसायिक चिंतन अभिलेख
- संस्थागत सहयोग मापन प्रपत्र
- सतत व्यावसायिक विकास सहभागिता अभिलेख

प्रत्येक शिक्षक के लिए एक संयुक्त दक्षता अभिलेख तैयार किया जाएगा। इसमें स्वमूल्यांकन और व्यवहारगत संकेतकों को अलग-अलग रखा जाएगा ताकि केवल आत्मधारणा को वास्तविक दक्षता का प्रतिनिधि न माना जाए।

४.२ मुख्य मापन आयाम

शिक्षक व्यावसायिक दक्षता को आठ प्रमुख आयामों में विभाजित किया गया है—

विषयगत एवं शिक्षण ज्ञान: विषयवस्तु की स्पष्टता तथा उसे विद्यार्थियों की आवश्यकता के अनुरूप प्रस्तुत करने की क्षमता।

शिक्षण नियोजन: उद्देश्य, गतिविधि, संसाधन और मूल्यांकन के बीच तार्किक संबंध स्थापित करने की क्षमता।

समावेशी व्यवहार: विभिन्न क्षमताओं और सामाजिक पृष्ठभूमियों वाले विद्यार्थियों के लिए शिक्षण में आवश्यक समायोजन।

बहुभाषिक संवेदनशीलता: विद्यार्थियों की परिचित भाषाओं को अर्थ-निर्माण और सहभागिता में सहायक बनाना।

मूल्यांकन विवेक: प्राप्त प्रमाणों के आधार पर शिक्षण-निर्णय बदलने की क्षमता।

प्रौद्योगिकी-सहायक शिक्षण: उपलब्ध तकनीकी संसाधनों का शैक्षिक उद्देश्य के अनुरूप विवेकपूर्ण उपयोग।

चिंतनशील अभ्यास: अपने शिक्षण की समीक्षा, त्रुटि पहचान और सुधारात्मक योजना तैयार करने की प्रवृत्ति।

सतत व्यावसायिक अधिगम: कार्यशाला, सहकर्मी संवाद, स्वअध्ययन और अनुभवजन्य सीख को व्यावसायिक विकास से जोड़ने की क्षमता।

४.३ आँकड़ा पूर्व-संसाधन

संग्रहित आँकड़ों को विश्लेषण से पहले अनेक चरणों से गुजारा जाएगा। अपूर्ण उत्तरों की पहचान की जाएगी और अत्यधिक अपूर्ण अभिलेखों

को विश्लेषण से बाहर रखा जाएगा। सीमित अनुपस्थित मानों को संबंधित आयाम के मध्यक मान से समायोजित किया जाएगा।

विभिन्न मापन प्रपत्रों के अंक अलग-अलग परास में होने के कारण उन्हें मानकीकृत किया जाएगा। ऋणात्मक प्रकृति वाले कथनों के अंकों को विपरीत रूप से पुनःकूटित किया जाएगा ताकि सभी आयामों में उच्च अंक बेहतर दक्षता को व्यक्त करें।

अत्यधिक असामान्य मानों की पहचान चतुर्थक सीमा पद्धति द्वारा की जाएगी। लेकिन किसी शिक्षक का वास्तविक निम्न या उच्च प्रदर्शन केवल सांख्यिकीय असामान्यता के कारण हटाया नहीं जाएगा। ऐसे मामलों को कक्षा-अवलोकन और अन्य स्रोतों से मिलान करने के बाद ही अंतिम निर्णय लिया जाएगा।

स्वमूल्यांकन और अवलोकित प्रदर्शन के बीच अंतर को निम्न प्रकार से व्यक्त किया जाएगा—

दक्षता-संरेखण अंतर = स्वमूल्यांकित दक्षता – अवलोकित दक्षता

शून्य के निकट मान उच्च संरेखण को व्यक्त करेगा। बड़ा धनात्मक मान यह दर्शाएगा कि शिक्षक अपनी दक्षता को वास्तविक व्यवहार की तुलना में अधिक आँक रहा है।

विश्लेषणात्मक संरचना

अध्ययन केवल पारंपरिक सहसंबंध विश्लेषण तक सीमित नहीं रहेगा। शिक्षक दक्षता को प्रभावित करने वाले अनेक परस्पर संबंधित आयामों के कारण एक बहुस्तरीय पूर्वानुमान संरचना प्रस्तावित की गई है।

प्रथम स्तर पर वर्णनात्मक विश्लेषण के माध्यम से प्रत्येक दक्षता आयाम का औसत, प्रसरण और वितरण देखा जाएगा। द्वितीय स्तर पर प्रशिक्षण परिवर्तन, संस्थागत सहयोग, चिंतनशील अभ्यास और व्यावसायिक विकास सहभागिता के साथ दक्षता के संबंध की जाँच की जाएगी।

तृतीय स्तर पर शिक्षकों को उनकी दक्षता संरचना के आधार पर विभिन्न व्यावसायिक रूपरेखाओं में वर्गीकृत किया जाएगा। अपेक्षित रूप से चार प्रकार की रूपरेखाएँ उभर सकती हैं—

१. **उच्च दक्षता–उच्च संरेखण समूह**

२. **उच्च आत्मधारणा–निम्न व्यवहार समूह**

३. **मध्यम दक्षता–उच्च विकास संभावना समूह**

४. **निम्न दक्षता–निम्न संस्थागत सहयोग समूह**

यह वर्गीकरण केवल कुल अंक पर आधारित न होकर दक्षताओं के संयोजन पर आधारित होगा।

प्रशिक्षण रणनीति

पूर्वानुमान विश्लेषण के लिए संपूर्ण आँकड़ों को प्रशिक्षण, सत्यापन और परीक्षण समूहों में विभाजित किया जाएगा। लगभग साठ प्रतिशत अभिलेख प्रशिक्षण के लिए, बीस प्रतिशत सत्यापन के लिए और शेष बीस प्रतिशत स्वतंत्र परीक्षण के लिए रखे जाएँगे।

नमूना विभाजन करते समय विद्यालय स्तर और भौगोलिक स्थिति का संतुलन बनाए रखा जाएगा ताकि किसी एक विद्यालय या क्षेत्र के शिक्षक अत्यधिक रूप से किसी एक समूह में न आ जाएँ।

विश्लेषण में वृक्ष-आधारित क्रमिक संवर्धन पद्धति का उपयोग प्रस्तावित है, क्योंकि यह सीधी रेखीय संरचना तक सीमित न रहकर विभिन्न दक्षता आयामों के जटिल संबंधों को पहचान सकती है। तुलना के लिए सरल बहुचर प्रतिगमन को आधार पद्धति के रूप में रखा जाएगा।

विश्लेषण का उद्देश्य केवल यह बताना नहीं होगा कि कौन-सा शिक्षक उच्च या निम्न दक्षता वाला है, बल्कि यह पहचानना होगा कि उस परिणाम के पीछे कौन-से कारक सर्वाधिक प्रभावशाली हैं।

मूल्यांकन मानदंड

विश्लेषण की गुणवत्ता के परीक्षण के लिए निम्न मानदंड प्रस्तावित हैं—

संतुलित शुद्धता: सभी दक्षता समूहों में वर्गीकरण की समग्र गुणवत्ता।

समष्टिगत समन्वित माप: प्रत्येक श्रेणी की शुद्धता और पुनर्प्राप्ति को समान महत्त्व देकर समग्र प्रदर्शन का आकलन।

माध्य निरपेक्ष त्रुटि: वास्तविक और अनुमानित दक्षता अंक के बीच औसत अंतर।

वर्गमूलित माध्य वर्ग त्रुटि: बड़ी त्रुटियों को अधिक भार देते हुए पूर्वानुमान विचलन का परीक्षण।

व्याख्यायित प्रसरण अनुपात: मॉडल द्वारा व्यावसायिक दक्षता में उपस्थित परिवर्तनशीलता के कितने भाग को समझाया गया।

संरेखण विचलन: स्वमूल्यांकन और व्यवहारगत प्रदर्शन के बीच अनुमानित अंतर की शुद्धता।

इस शोध में केवल उच्च पूर्वानुमान क्षमता को पर्याप्त नहीं माना जाएगा। विश्लेषण की व्याख्येयता भी आवश्यक होगी ताकि निष्कर्ष शिक्षक शिक्षा संस्थानों और विद्यालयी नेतृत्व के लिए उपयोगी बन सकें।

परिणाम और चर्चा

प्रस्तावित विश्लेषणात्मक संरचना के आधार पर यह अपेक्षा की जाती है कि शिक्षक शिक्षा में अनुभव किए गए परिवर्तन और समग्र व्यावसायिक दक्षता के बीच सकारात्मक संबंध दिखाई देगा, किंतु यह संबंध सभी शिक्षकों में समान नहीं होगा। संस्थागत परिस्थितियाँ, अभ्यास के अवसर और चिंतनशील प्रवृत्ति इस संबंध की शक्ति को प्रभावित कर सकती हैं।

विशेष रूप से यह अनुमान है कि **चिंतनशील अभ्यास** और **मूल्यांकन विवेक** उन आयामों में सम्मिलित होंगे जिनका वास्तविक कक्षा-दक्षता से सबसे मजबूत संबंध दिखाई देगा। इसका कारण यह है कि शिक्षक का वास्तविक व्यावसायिक व्यवहार केवल पूर्वनिर्धारित विधियों के उपयोग पर निर्भर नहीं रहता; उसे विद्यार्थियों की प्रतिक्रिया के आधार पर लगातार निर्णय बदलने पड़ते हैं।

समावेशी व्यवहार में भी प्रशिक्षण और व्यवहार के बीच उल्लेखनीय अंतर मिलने की संभावना है। शिक्षक समावेशन के सिद्धांतों को स्वीकार कर सकता है, किंतु विविध अधिगम आवश्यकताओं के अनुरूप गतिविधि, प्रश्न और मूल्यांकन बदलना अधिक जटिल व्यावहारिक दक्षता है।

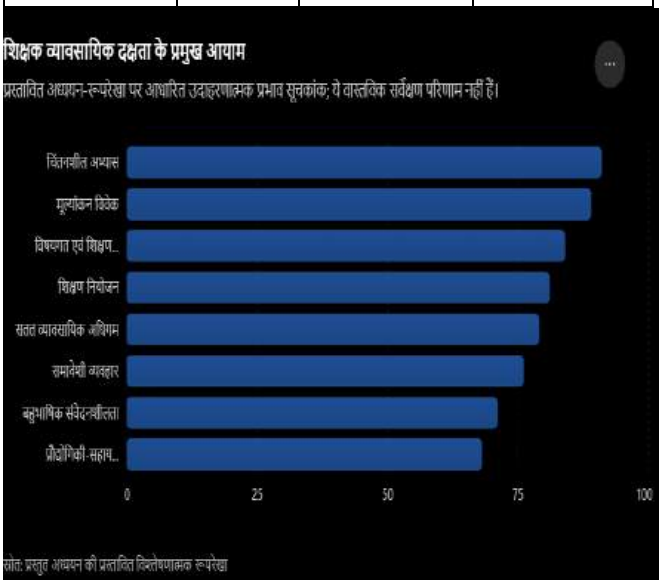
प्रौद्योगिकी-सहायक शिक्षण के संदर्भ में उपयोग की आवृत्ति और उपयोग की शैक्षिक गुणवत्ता में स्पष्ट भेद मिलने की संभावना है। केवल डिजिटल संसाधनों का अधिक प्रयोग उच्च व्यावसायिक दक्षता का संकेत नहीं होगा। अधिक महत्वपूर्ण यह होगा कि शिक्षक उस संसाधन को सही उद्देश्य, सही विद्यार्थी समूह और सही समय पर प्रयोग करता है या नहीं।

संस्थागत सहयोग का प्रभाव विशेष रूप से उल्लेखनीय हो सकता है। जिन विद्यालयों में सहकर्मी संवाद, पाठ अवलोकन, साझा योजना और नेतृत्व-समर्थन उपलब्ध होगा, वहाँ प्रशिक्षित दक्षताओं के व्यवहार में रूपांतरण की संभावना अधिक होगी। इसका अर्थ यह है कि शिक्षक शिक्षा की प्रभावशीलता को केवल प्रशिक्षण संस्थान के आधार पर नहीं

समझा जा सकता; विद्यालय स्वयं व्यावसायिक अधिगम का महत्वपूर्ण स्थल है।

सारणी १ : प्रस्तावित विश्लेषण में प्रमुख दक्षता आयामों की तुलनात्मक स्थिति

दक्षता आयाम	अपेक्षित औसत स्तर	स्वमूल्यांकन–व्यवहार अंतर	व्यावसायिक दक्षता पर अनुमानित प्रभाव
विषयगत एवं शिक्षण ज्ञान	उच्च	निम्न	उच्च
शिक्षण नियोजन	मध्यम से उच्च	मध्यम	उच्च
समावेशी व्यवहार	मध्यम	अपेक्षाकृत उच्च	उच्च
बहुभाषिक संवेदनशीलता	मध्यम	मध्यम	मध्यम से उच्च
मूल्यांकन विवेक	मध्यम	मध्यम	अत्यधिक उच्च
प्रौद्योगिकी-सहायक शिक्षण	मध्यम से उच्च	उच्च	मध्यम
चिंतनशील अभ्यास	मध्यम	निम्न से मध्यम	अत्यधिक उच्च
सतत व्यावसायिक अधिगम	मध्यम से उच्च	निम्न	उच्च



सारणी से स्पष्ट वैचारिक संकेत मिलता है कि सभी दक्षता आयामों का योगदान समान नहीं है। कुछ शिक्षक विषयगत ज्ञान में मजबूत हो सकते हैं, लेकिन यदि उनमें मूल्यांकन विवेक और चिंतनशील क्षमता सीमित है तो बदलती कक्षा परिस्थितियों में उनकी प्रभावशीलता घट सकती है।

यह परिणाम शिक्षक शिक्षा के लिए महत्वपूर्ण है। प्रशिक्षण कार्यक्रमों को केवल विषयवस्तु और शिक्षण-विधियों की सूची पर आधारित रखने के बजाय उन परिस्थितियों का निर्माण करना चाहिए जिनमें प्रशिक्षु शिक्षक वास्तविक समस्याओं का निदान करे, अपना निर्णय स्पष्ट करे और परिणाम के आधार पर रणनीति बदले।

व्यावसायिक दक्षता-संरेखण की व्याख्या

इस शोध का सबसे महत्वपूर्ण योगदान केवल व्यावसायिक दक्षता का औसत स्तर निर्धारित करना नहीं, बल्कि स्वधारित और व्यवहारगत दक्षता के बीच अंतर की पहचान करना है।

यदि कोई शिक्षक स्वयं को अत्यधिक दक्ष मानता है किंतु अवलोकन में उसकी समावेशी शिक्षण क्षमता, मूल्यांकन विवेक या विद्यार्थी सहभागिता सीमित पाई जाती है, तो केवल अतिरिक्त प्रशिक्षण देना पर्याप्त समाधान नहीं होगा। ऐसे मामलों में प्रतिपुष्टि, सहकर्मी अवलोकन और चिंतनशील अभ्यास की आवश्यकता अधिक होगी।

इसके विपरीत कुछ शिक्षक स्वयं को औसत दक्ष मान सकते हैं लेकिन वास्तविक कक्षा में प्रभावशाली व्यवहार प्रदर्शित कर सकते हैं। ऐसे शिक्षक विद्यालयी व्यावसायिक अधिगम समुदाय में मार्गदर्शक भूमिका निभा सकते हैं।

इस प्रकार शिक्षक मूल्यांकन का उद्देश्य दंडात्मक वर्गीकरण नहीं, बल्कि व्यावसायिक विकास की आवश्यकता की पहचान होना चाहिए।

सीमाएँ

प्रस्तावित अध्ययन की कुछ महत्वपूर्ण सीमाएँ स्वीकार करना आवश्यक है। प्रथम, शिक्षक की व्यावसायिक दक्षता एक जटिल और संदर्भ-निर्भर अवधारणा है, जिसे किसी एक प्रश्नावली अथवा एक बार के कक्षा-अवलोकन से पूरी तरह नहीं मापा जा सकता।

द्वितीय, कक्षा-अवलोकन के दौरान शिक्षक अपने सामान्य व्यवहार से अधिक योजनाबद्ध प्रदर्शन कर सकता है। इसे कम करने के लिए एक से अधिक अवलोकन उपयोगी होंगे।

तृतीय, विद्यालयी संसाधनों की उपलब्धता शिक्षक व्यवहार को प्रभावित कर सकती है। इसलिए सीमित संसाधनों के कारण किसी रणनीति का प्रयोग न कर पाने को सीधे व्यक्तिगत अक्षमता नहीं माना जाना चाहिए।

चतुर्थ, राष्ट्रीय शिक्षा नीति से संबंधित परिवर्तन अलग-अलग राज्यों, संस्थानों और विद्यालयों में समान गति से लागू नहीं हुए हैं। अतः किसी एक क्षेत्र के निष्कर्ष पूरे देश पर सीधे लागू नहीं किए जाने चाहिए।

पंचम, प्रस्तावित विश्लेषण शिक्षक दक्षता के महत्वपूर्ण संकेतकों को पहचान सकता है, किंतु सांख्यिकीय संबंध स्वयं कारण-कार्य संबंध को सिद्ध नहीं करते।

भावी अनुसंधान की दिशा

भविष्य में इस अध्ययन को दीर्घकालिक रूप दिया जा सकता है जिसमें समान शिक्षकों का दो या तीन शैक्षणिक वर्षों तक अनुसरण किया जाए। इससे यह स्पष्ट होगा कि प्रशिक्षण, अनुभव और संस्थागत सहयोग के कारण दक्षता में वास्तविक परिवर्तन कैसे होता है।

शिक्षक शिक्षा संस्थानों और विद्यालयों को जोड़ते हुए अभ्यास-आधारित व्यावसायिक विकास मॉडल विकसित किए जा सकते हैं। प्रशिक्षण के बाद शिक्षक को नियमित कक्षा-अवलोकन, सहकर्मी प्रतिपुष्टि और स्वचिंतन के अवसर उपलब्ध कराकर यह देखा जा सकता है कि दक्षता-संरेखण अंतर किस सीमा तक घटता है।

आगे के अध्ययन में शिक्षक दक्षता और विद्यार्थी सहभागिता, अधिगम प्रगति, उपस्थिति तथा कक्षा वातावरण के बीच संबंध का परीक्षण किया जा सकता है। इससे यह स्पष्ट हो सकेगा कि कौन-सी शिक्षक दक्षताएँ विद्यार्थी स्तर पर सबसे अधिक प्रभाव उत्पन्न करती हैं।

ग्रामीण और नगरीय विद्यालयों, सरकारी और निजी विद्यालयों तथा अलग-अलग अनुभव स्तर वाले शिक्षकों के बीच तुलनात्मक अध्ययन भी उपयोगी होगा। इससे शिक्षक विकास के लिए एक समान प्रशिक्षण व्यवस्था के स्थान पर संदर्भ-विशिष्ट व्यावसायिक सहयोग मॉडल विकसित किए जा सकते हैं।

शिक्षक के व्यावसायिक विकास हेतु व्यक्तिगत दक्षता-प्रोफ़ाइल आधारित सुझाव विकसित करना भी एक महत्वपूर्ण भावी दिशा हो सकती है। उदाहरणतः यदि किसी शिक्षक में विषयज्ञान मजबूत है किंतु समावेशी व्यवहार कमजोर है, तो उसके लिए सामान्य प्रशिक्षण के स्थान पर विशिष्ट समावेशी शिक्षण अभ्यास अधिक उपयुक्त होगा।

निष्कर्ष

राष्ट्रीय शिक्षा नीति २०२० ने शिक्षक शिक्षा को एक व्यापक परिवर्तनशील प्रक्रिया के रूप में देखने की दिशा को सुदृढ़ किया है। शिक्षक की भूमिका अब केवल विषयवस्तु संप्रेषित करने तक सीमित नहीं है; उससे शिक्षण नियोजन, समावेशन, बहुभाषिक संवेदनशीलता, मूल्यांकन विवेक, प्रौद्योगिकी का उचित उपयोग, चिंतनशील अभ्यास और सतत व्यावसायिक अधिगम की अपेक्षा भी की जाती है।

प्रस्तुत अध्ययन का केंद्रीय तर्क यह है कि शिक्षक शिक्षा में सुधार का वास्तविक मूल्यांकन प्रशिक्षण की उपलब्धता या प्रशिक्षण में सहभागिता से नहीं, बल्कि इस बात से किया जाना चाहिए कि प्रशिक्षण से प्राप्त दक्षताएँ विद्यालयी व्यवहार में किस सीमा तक रूपांतरित होती हैं।

इसी उद्देश्य से **व्यावसायिक दक्षता-संरेखण अंतर** की अवधारणा प्रस्तावित की गई है। यह अवधारणा शिक्षक की स्वधारित क्षमता और उसके वास्तविक कक्षा-व्यवहार के बीच अंतर को मापने में सहायक हो सकती है।

अध्ययन यह भी स्पष्ट करता है कि शिक्षक दक्षता केवल व्यक्ति की विशेषता नहीं है। संस्थागत सहयोग, व्यावसायिक संवाद, संसाधनों की उपलब्धता, चिंतनशील अभ्यास और नेतृत्व का वातावरण इस दक्षता के विकास को प्रभावित करते हैं। इसलिए प्रभावी शिक्षक शिक्षा नीति को प्रशिक्षण संस्थान से विद्यालय तक एक सतत व्यावसायिक विकास श्रृंखला बनानी होगी।

अंततः राष्ट्रीय शिक्षा नीति २०२० के उद्देश्यों को विद्यालय स्तर पर प्रभावी बनाने के लिए शिक्षक शिक्षा को प्रमाण-पत्र केंद्रित व्यवस्था से आगे बढ़ाकर **प्रदर्शन-आधारित, चिंतनशील, संदर्भ-संवेदी और सतत व्यावसायिक अधिगम व्यवस्था** में परिवर्तित करना आवश्यक है। यही परिवर्तन शिक्षक की वास्तविक व्यावसायिक दक्षता को मजबूत करते हुए शिक्षा की गुणवत्ता में स्थायी सुधार का आधार बन सकता है।

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- *राष्ट्रीय शैक्षिक अनुसंधान और प्रशिक्षण परिषद। (2023). विद्यालयी शिक्षा के लिए राष्ट्रीय पाठ्यचर्या की रूपरेखा 2023. नई दिल्ली: राष्ट्रीय शैक्षिक अनुसंधान और प्रशिक्षण परिषद। यह रूपरेखा NEP 2020 के अनुरूप शिक्षण-अधिगम और शिक्षक की भूमिका में आए परिवर्तनों के अध्ययन के लिए उपयोगी है। राष्ट्रीय शैक्षिक अनुसंधान और प्रशिक्षण परिषद – आधिकारिक स्रोत*
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- *विश्वविद्यालय अनुदान आयोग। (2023). Malaviya Mission Teacher Training Programme Guidelines. New Delhi: University Grants Commission. इसमें उच्च शिक्षा के शिक्षकों की क्षमता वृद्धि, प्रशिक्षण और सतत व्यावसायिक विकास पर बल दिया गया है। विश्वविद्यालय अनुदान आयोग के आधिकारिक दिशानिर्देश*
- *राष्ट्रीय अध्यापक शिक्षा परिषद। (2024). NCTE (Recognition Norms and Procedure) Amendment Regulations, 2024: Integrated Teacher Education Programme. नई दिल्ली: राष्ट्रीय अध्यापक शिक्षा परिषद। यह शिक्षक शिक्षा कार्यक्रमों के NEP 2020-अनुरूप संस्थागत परिवर्तन को समझने के लिए उपयोगी आधिकारिक स्रोत है। एनसीटीई एकीकृत शिक्षक शिक्षा कार्यक्रम*
- *राष्ट्रीय अध्यापक शिक्षा परिषद। (2024). National Professional Standards for Teachers: Guiding Document. New Delhi: NCTE. इसमें शिक्षक की व्यावसायिक दक्षता को ज्ञान, कौशल, मूल्यों, अभिवृत्तियों, प्रभावी शिक्षण तथा करियर के विभिन्न चरणों से संबद्ध किया गया है। शिक्षकों के लिए राष्ट्रीय व्यावसायिक मानक – पूर्ण दस्तावेज़*

अध्याय 18: NEP 2020 के संदर्भ में शिक्षा में प्रौद्योगिकी एकीकरण और डिजिटल समानता की चुनौतियाँ

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सारांश— राष्ट्रीय शिक्षा नीति 2020 ने प्रौद्योगिकी को शैक्षिक पहुँच, गुणवत्ता, प्रशासन तथा सीखने के अवसरों में सुधार के महत्वपूर्ण माध्यम के रूप में स्वीकार किया है। फिर भी विद्यालयों और विद्यार्थियों के बीच डिजिटल संसाधनों की उपलब्धता तथा उनके प्रभावी शैक्षिक उपयोग में पर्याप्त अंतर दिखाई देता है। यह अध्ययन प्रौद्योगिकी एकीकरण और डिजिटल समानता के संबंध को बहुस्तरीय दृष्टिकोण से समझने का प्रयास करता है। इसमें उपकरण उपलब्धता के साथ संपर्क की गुणवत्ता, शिक्षक दक्षता, भाषायी पहुँच, पारिवारिक सहायता और समावेशी उपयोग को प्रमुख आयाम माना गया है। अध्ययन का केंद्रीय तर्क है कि केवल डिजिटल साधन उपलब्ध करा देना समान शैक्षिक अवसर सुनिश्चित करने के लिए पर्याप्त नहीं है। प्रस्तावित विश्लेषण विद्यार्थियों के वास्तविक उपयोग, सहभागिता और सीखने के लाभ के बीच उत्पन्न असमानताओं की पहचान करता है।

यह दृष्टिकोण राष्ट्रीय शिक्षा नीति 2020 के समानता, समावेशन और प्रौद्योगिकी-समर्थित शिक्षा संबंधी उद्देश्यों के मूल्यांकन के लिए उपयोगी आधार प्रदान करता है। अध्ययन से प्राप्त निष्कर्ष डिजिटल संसाधनों के वितरण से आगे बढ़कर न्यायसंगत, भाषायी रूप से समावेशी और शिक्षक-समर्थित डिजिटल शिक्षा व्यवस्था विकसित करने में सहायक हो सकते हैं।

मुख्य शब्द— डिजिटल समानता, प्रौद्योगिकी एकीकरण, शैक्षिक समावेशन, डिजिटल पहुँच, शिक्षक दक्षता, राष्ट्रीय शिक्षा नीति 2020

परिचय

भारतीय शिक्षा व्यवस्था में प्रौद्योगिकी का उपयोग पिछले कुछ वर्षों में केवल सहायक शिक्षण साधन के रूप में नहीं, बल्कि शैक्षिक संरचना के महत्वपूर्ण घटक के रूप में उभरा है। राष्ट्रीय शिक्षा नीति 2020 ने शिक्षण, अधिगम, मूल्यांकन, प्रशासन, शिक्षक व्यावसायिक विकास तथा शैक्षिक संसाधनों के प्रसार में प्रौद्योगिकी की व्यापक भूमिका को मान्यता दी है। नीति में यह भी स्पष्ट किया गया है कि प्रौद्योगिकी के शैक्षिक लाभों का विस्तार तभी सार्थक होगा जब डिजिटल विभाजन और समानता से जुड़ी समस्याओं को व्यवस्थित रूप से संबोधित किया जाए।

भारत जैसे सामाजिक, आर्थिक, भाषायी और भौगोलिक विविधता वाले देश में प्रौद्योगिकी एकीकरण का अर्थ केवल कक्षाओं में संगणक, प्रदर्शन उपकरण अथवा अंतर्जाल सुविधा स्थापित करना नहीं है। किसी विद्यार्थी के लिए प्रौद्योगिकी वास्तव में उपयोगी तभी बनती है जब वह नियमित रूप से उपकरण तक पहुँच सके, उपयुक्त भाषा में सामग्री समझ सके, तकनीकी समस्याओं से निपट सके, शिक्षक से मार्गदर्शन प्राप्त कर सके और डिजिटल गतिविधियों को अपने अधिगम से जोड़ सके। अतः संसाधन की उपलब्धता और संसाधन से उत्पन्न शैक्षिक लाभ के बीच स्पष्ट अंतर करना आवश्यक है।

विद्यालयी स्तर पर उपलब्ध नवीनतम सरकारी आँकड़े भी इस अंतर की प्रासंगिकता को रेखांकित करते हैं। वर्ष 2024–25 के एकीकृत जिला शिक्षा सूचना प्रणाली के अनुसार भारत में लगभग 14.71 लाख विद्यालय दर्ज किए गए। इनमें लगभग 9.52 लाख विद्यालयों में संगणक सुविधा तथा लगभग 9.34 लाख विद्यालयों में अंतर्जाल सुविधा दर्ज थी। शिक्षण प्रयोजनों के लिए कार्यशील संगणक सुविधा वाले विद्यालयों की संख्या लगभग 8.53 लाख थी। इससे स्पष्ट होता है कि प्रौद्योगिकी का प्रसार व्यापक हुआ है, किंतु प्रत्येक विद्यालय समान स्तर पर कार्यशील डिजिटल अधोसंरचना से युक्त नहीं है।

यह स्थिति डिजिटल समानता को एक अधिक जटिल शोध विषय बनाती है। उदाहरण के लिए, दो विद्यालयों में संगणक उपलब्ध हो सकते हैं, परंतु एक विद्यालय में पर्याप्त उपकरण, प्रशिक्षित शिक्षक, स्थिर संपर्क और स्थानीय भाषा की सामग्री हो सकती है, जबकि दूसरे विद्यालय में सीमित उपकरण, बार-बार बाधित संपर्क और अपर्याप्त शिक्षक प्रशिक्षण हो सकता है। प्रशासनिक आँकड़ों में दोनों विद्यालय "डिजिटल सुविधा वाले" माने जा सकते हैं, जबकि विद्यार्थियों का वास्तविक अनुभव अत्यंत भिन्न हो सकता है। इसी कारण प्रस्तुत अध्ययन डिजिटल समानता को केवल भौतिक संसाधनों की समान उपलब्धता के रूप में नहीं देखता।



Fig. 1: डिजिटल शिक्षा में समान अवसर: प्रौद्योगिकी, समावेशन और चुनौतियाँ

राष्ट्रीय शिक्षा नीति 2020 में डिजिटल शिक्षा के विस्तार के साथ-साथ उसके संभावित जोखिमों का भी उल्लेख किया गया है। नीति यह स्वीकार करती है कि डिजिटल माध्यमों का लाभ तब तक सार्वभौमिक नहीं हो सकता जब तक उपकरणों और संपर्क की वहनीयता, शिक्षक तैयारी और समान पहुँच जैसी चुनौतियों का समाधान नहीं किया जाता। साथ ही, नीति प्रौद्योगिकी आधारित हस्तक्षेपों को बड़े स्तर पर अपनाने से पूर्व संदर्भानुकूल परीक्षण और मूल्यांकन पर बल देती है। यह दृष्टिकोण इस अध्ययन के मूल तर्क के अनुरूप है कि केवल तकनीकी विस्तार को सफलता का संकेतक मानना अपर्याप्त है।

डिजिटल समानता की पहली परत **भौतिक पहुँच** से संबंधित है। इसमें संगणक, चल उपकरण, विद्युत आपूर्ति, अंतर्जाल संपर्क और आवश्यक सहायक उपकरण सम्मिलित हैं। ग्रामीण, पर्वतीय, जनजातीय अथवा आर्थिक रूप से पिछड़े क्षेत्रों में इन संसाधनों की गुणवत्ता और नियमित उपलब्धता में अंतर विद्यार्थियों के सीखने के अवसरों को प्रभावित कर सकता है। एक परिवार में केवल एक साझा उपकरण होना भी उस स्थिति से भिन्न है जिसमें प्रत्येक विद्यार्थी को अध्ययन के लिए स्वतंत्र उपकरण उपलब्ध हो।

दूसरी परत **उपयोग-क्षमता** से जुड़ी है। उपकरण उपलब्ध होने मात्र से यह सुनिश्चित नहीं होता कि विद्यार्थी उसका शैक्षिक उद्देश्य से प्रभावी उपयोग कर सकेगा। डिजिटल सामग्री खोजना, उसकी विश्वसनीयता समझना, निर्देशों का पालन करना, संवाद करना, कार्य प्रस्तुत करना और प्राप्त प्रतिक्रिया का उपयोग करना अलग-अलग क्षमताएँ हैं। इन क्षमताओं में असमानता डिजिटल शिक्षा के परिणामों में अंतर पैदा कर सकती है।

तीसरी परत **शिक्षक-संबंधी तैयारी** है। पारंपरिक कक्षा में प्रभावी शिक्षण करने वाला प्रत्येक शिक्षक स्वतः प्रौद्योगिकी-समर्थित वातावरण में समान दक्षता से कार्य करेगा, ऐसा मानना उचित नहीं है। राष्ट्रीय शिक्षा नीति ने भी डिजिटल माध्यमों में प्रभावी शिक्षण के लिए शिक्षक प्रशिक्षण की आवश्यकता को स्वीकार किया है। शिक्षक को केवल उपकरण चलाना ही नहीं, बल्कि डिजिटल सामग्री का चयन, मिश्रित शिक्षण योजना, विद्यार्थी सहभागिता, डिजिटल मूल्यांकन और विविध अधिगम आवश्यकताओं के अनुरूप अनुकूलन भी सीखना पड़ता है।

चौथी परत **भाषायी समानता** से संबंधित है। भारत में विद्यार्थियों की मातृभाषाएँ और शिक्षण भाषाएँ अत्यंत विविध हैं। यदि डिजिटल सामग्री कुछ सीमित भाषाओं में ही उपलब्ध हो, तो उपकरण प्राप्त कर लेने के बाद भी विद्यार्थी उसका समान लाभ नहीं उठा सकता। राष्ट्रीय शिक्षा नीति बहुभाषिकता तथा मातृभाषा के शैक्षिक महत्त्व को प्रमुख स्थान देती है। शिक्षा मंत्रालय भी समान पहुँच, डिजिटल साक्षरता और विविध भाषायी आवश्यकताओं को शिक्षा की गुणवत्ता से जोड़ता है। अतः डिजिटल समानता का मूल्यांकन करते समय सामग्री की भाषायी उपयुक्तता को अनिवार्य संकेतक माना जाना चाहिए।

पाँचवीं परत **सामाजिक और पारिवारिक समर्थन** की है। समान विद्यालयी संसाधनों के बावजूद घर पर शांत अध्ययन स्थान, अभिभावकीय सहायता, उपकरण उपलब्धता और डिजिटल गतिविधियों के लिए समय में अंतर विद्यार्थियों के अनुभवों को प्रभावित कर सकता है। इसलिए विद्यालय के स्तर पर उपलब्ध तकनीकी संसाधनों को विद्यार्थी की वास्तविक डिजिटल पहुँच के समान नहीं माना जा सकता।

छठी परत **समावेशन और सुगम्यता** से संबंधित है। दृष्टि, श्रवण, चलन अथवा अन्य विशेष आवश्यकताओं वाले विद्यार्थियों के लिए डिजिटल संसाधन तभी समानतापूर्ण होंगे जब सामग्री और उपकरण उनकी आवश्यकताओं के अनुरूप हों। यदि मंच, सामग्री या शिक्षण गतिविधि सुगम नहीं है तो प्रौद्योगिकी, समानता बढ़ाने के बजाय मौजूदा अंतर को और गहरा कर सकती है।

अंतरराष्ट्रीय स्तर पर भी शिक्षा में प्रौद्योगिकी के मूल्यांकन को केवल तकनीकी विस्तार से जोड़ने के प्रति सावधानी व्यक्त की गई है। संयुक्त राष्ट्र शैक्षिक, वैज्ञानिक और सांस्कृतिक संगठन की वर्ष 2023 की वैश्विक शिक्षा निगरानी रिपोर्ट ने शिक्षा में प्रौद्योगिकी को प्रासंगिकता, समानता, विस्तार-क्षमता और स्थायित्व जैसे आयामों से देखने की आवश्यकता पर बल दिया। यह दृष्टिकोण स्पष्ट करता है कि किसी प्रौद्योगिकी का शैक्षिक मूल्य इस बात से निर्धारित होना चाहिए कि वह किन विद्यार्थियों तक पहुँचती है, किन परिस्थितियों में उपयोग होती है तथा किस प्रकार के अधिगम लाभ उत्पन्न करती है।

प्रस्तुत अध्ययन इसी आधार पर **चार-स्तरीय डिजिटल समानता संरचना** प्रस्तावित करता है—संसाधन पहुँच, प्रभावी उपयोग, सक्रिय सहभागिता और अधिगम लाभ। इस संरचना का उद्देश्य यह पहचानना है कि असमानता किस स्तर पर उत्पन्न हो रही है। उदाहरणतः कोई विद्यार्थी उपकरण तक पहुँच रख सकता है, परंतु भाषा संबंधी समस्या के कारण सामग्री का उपयोग न कर पाए; कोई अन्य विद्यार्थी सामग्री समझ सकता है, पर शिक्षक मार्गदर्शन के अभाव में गतिविधि में नियमित भाग न ले; तीसरा विद्यार्थी सक्रिय भागीदारी के बावजूद अपर्याप्त प्रतिक्रिया के कारण अपेक्षित शैक्षिक लाभ प्राप्त न कर पाए। इस प्रकार डिजिटल समानता को निरंतर प्रक्रिया के रूप में समझना आवश्यक है।

अध्ययन का उद्देश्य

इस अध्ययन का प्रमुख उद्देश्य राष्ट्रीय शिक्षा नीति 2020 के संदर्भ में शिक्षा में प्रौद्योगिकी एकीकरण और डिजिटल समानता के मध्य संबंध का विश्लेषण करना तथा यह निर्धारित करना है कि भौतिक पहुँच के अतिरिक्त कौन-से सामाजिक, शैक्षिक और भाषायी कारक विद्यार्थियों के वास्तविक डिजिटल अधिगम अवसरों को प्रभावित करते हैं।

विशेष रूप से अध्ययन निम्न प्रश्नों की जाँच करेगा—

1. क्या उपकरण और संपर्क की उपलब्धता विद्यार्थियों की सक्रिय डिजिटल सहभागिता को पर्याप्त रूप से स्पष्ट करती है?
2. शिक्षक की प्रौद्योगिकी-समर्थित शिक्षण दक्षता डिजिटल संसाधनों के शैक्षिक उपयोग को किस सीमा तक प्रभावित करती है?
3. भाषायी सुगमता और घरेलू समर्थन डिजिटल सहभागिता तथा अधिगम लाभ को कैसे प्रभावित करते हैं?
4. क्या डिजिटल समानता के संसाधन, उपयोग, सहभागिता और उपलब्धि स्तरों के बीच मापन योग्य अंतर पाया जाता है?
5. किन परिस्थितियों में प्रौद्योगिकी एकीकरण मौजूदा शैक्षिक असमानताओं को कम करने के बजाय उन्हें बनाए रख सकता है?

साहित्य समीक्षा

2.1 राष्ट्रीय शिक्षा नीति 2020 और प्रौद्योगिकी का शैक्षिक दृष्टिकोण

राष्ट्रीय शिक्षा नीति 2020 में प्रौद्योगिकी को शिक्षा की गुणवत्ता और पहुँच में सुधार के लिए व्यापक परिवर्तनकारी साधन के रूप में देखा गया है। नीति शिक्षण, मूल्यांकन, प्रशासन और शिक्षक विकास में प्रौद्योगिकी के उपयोग का समर्थन करती है, पर साथ ही संदर्भानुकूल मूल्यांकन की आवश्यकता पर बल देती है। राष्ट्रीय शैक्षिक प्रौद्योगिकी मंच की परिकल्पना भी इसी उद्देश्य से की गई कि शिक्षा क्षेत्र में प्रौद्योगिकी संबंधी निर्णय ज्ञान, अनुसंधान और अनुभव के आधार पर लिए जाएँ।

नीति के बाद विभिन्न राष्ट्रीय पहलों में डिजिटल शिक्षा अधोसंरचना, शिक्षक प्रशिक्षण, क्षेत्रीय भाषा आधारित शिक्षा तथा शैक्षिक संसाधनों के विस्तार को प्राथमिकता दी गई है। शिक्षा मंत्रालय द्वारा प्रकाशित कार्यान्वयन पहलों में राष्ट्रीय डिजिटल शिक्षा संरचना और राष्ट्रीय शैक्षिक प्रौद्योगिकी मंच जैसी व्यवस्थाएँ इस दिशा में संस्थागत प्रयासों को दर्शाती हैं।

2.2 डिजिटल विभाजन से डिजिटल समानता की ओर

प्रारंभिक डिजिटल विभाजन संबंधी अध्ययनों में मुख्य चिंता उपकरण और अंतर्जाल तक पहुँच की थी। किंतु शिक्षा के डिजिटलीकरण ने यह स्पष्ट किया कि पहुँच केवल पहली बाधा है। समान उपकरण उपलब्ध होने के बाद भी विद्यार्थियों की डिजिटल दक्षता, सामग्री उपयोग, मार्गदर्शन और सीखने के परिणाम समान नहीं होते। अतः डिजिटल समानता के अध्ययन में मात्र तकनीकी संसाधनों की संख्या के स्थान पर उनके वास्तविक उपयोग और शैक्षिक प्रभाव को सम्मिलित करना आवश्यक है।

विद्यालयों में संगणक और अंतर्जाल सुविधाओं की संख्या में वृद्धि सकारात्मक प्रगति को दर्शाती है, किंतु राष्ट्रीय स्तर पर सभी विद्यालयों में कार्यशील शिक्षण-उपयोगी संगणक उपलब्ध नहीं हैं। वर्ष 2024–25 के सरकारी आँकड़ों में संगणक सुविधा वाले विद्यालयों और शिक्षण प्रयोजन हेतु कार्यशील संगणक सुविधा वाले विद्यालयों की संख्या के बीच अंतर इसी तथ्य की ओर संकेत करता है। इसलिए भविष्य के मूल्यांकन में "सुविधा मौजूद है" और "सुविधा नियमित रूप से सीखने में उपयोग हो रही है" को अलग-अलग मापना आवश्यक है।

2.3 संपर्क की उपलब्धता बनाम संपर्क की गुणवत्ता

डिजिटल शिक्षा में अंतर्जाल सुविधा को प्रायः द्विआधारी रूप से देखा जाता है—उपलब्ध अथवा अनुपलब्ध। वास्तविक शैक्षिक व्यवहार में इसकी गति, स्थिरता, वहनीयता और समयबद्ध उपलब्धता अधिक महत्त्वपूर्ण हो सकती है। सीमित अथवा अस्थिर संपर्क वाले विद्यार्थी सीधे प्रसारण आधारित गतिविधियों में कठिनाई अनुभव कर सकते हैं, जबकि कम आँकड़ा-उपयोग वाली सामग्री अथवा पूर्व-संग्रहित संसाधनों के माध्यम से उनकी सहभागिता बढ़ाई जा सकती है। इसलिए संपर्क की गुणवत्ता को स्वतंत्र संकेतक मानना चाहिए।

2.4 शिक्षक की डिजिटल शिक्षण क्षमता

शिक्षक प्रौद्योगिकी और विद्यार्थी के बीच महत्त्वपूर्ण मध्यस्थ है। शिक्षण में प्रौद्योगिकी का प्रभाव केवल मंच अथवा उपकरण की विशेषताओं पर निर्भर नहीं करता; यह इस बात पर भी निर्भर करता है कि शिक्षक उसे पाठ्य उद्देश्य, विद्यार्थी स्तर और मूल्यांकन पद्धति से किस प्रकार जोड़ता है। राष्ट्रीय शिक्षा नीति डिजिटल और प्रत्यक्ष शिक्षण के बीच अध्यापन संबंधी अंतर को स्वीकार करती है और उपयुक्त शिक्षक प्रशिक्षण की आवश्यकता दर्शाती है।

इस दृष्टि से डिजिटल दक्षता को उपकरण संचालन तक सीमित करना पर्याप्त नहीं है। शिक्षक को सामग्री की उपयुक्तता का निर्णय, डिजिटल गतिविधियों की संरचना, विद्यार्थियों की सहभागिता का अवलोकन तथा सीखने की कठिनाइयों पर समयबद्ध प्रतिक्रिया देने की क्षमता भी आवश्यक होती है।

2.5 भाषायी विविधता और डिजिटल सामग्री

भारत की बहुभाषिक संरचना डिजिटल समानता की चर्चा में केंद्रीय स्थान रखती है। मातृभाषा अथवा परिचित भाषा में सामग्री की उपलब्धता विद्यार्थी की समझ, आत्मविश्वास और सहभागिता को प्रभावित कर सकती है। यदि तकनीकी मंच बहुभाषिक पहुँच प्रदान करता है पर प्रमुख सामग्री सीमित भाषाओं में उपलब्ध है, तो संरचनात्मक पहुँच और वास्तविक शैक्षिक पहुँच के बीच अंतर बना रहता है।

राष्ट्रीय शिक्षा नीति में भारतीय भाषाओं और मातृभाषा आधारित शिक्षा पर बल इसी संदर्भ में महत्त्वपूर्ण है। डिजिटल शिक्षा के लिए इसका अर्थ केवल अनुवाद उपलब्ध कराना नहीं, बल्कि सांस्कृतिक और भाषायी संदर्भ के अनुरूप सामग्री तैयार करना भी है।

2.6 सामाजिक-आर्थिक पृष्ठभूमि और घरेलू डिजिटल वातावरण

विद्यार्थी की डिजिटल शिक्षा विद्यालय की सीमा पर समाप्त नहीं होती। घर में उपकरण साझा करने की आवश्यकता, अध्ययन के लिए स्थान, अभिभावक की डिजिटल दक्षता और परिवार की आर्थिक क्षमता डिजिटल सीखने की निरंतरता को प्रभावित कर सकती है। कम आय वाले परिवार में उपकरण की मरम्मत, आँकड़ा व्यय अथवा उपकरण साझा करने जैसी परिस्थितियाँ नियमित सहभागिता में बाधा उत्पन्न कर सकती हैं।

इस कारण डिजिटल समानता का मूल्यांकन केवल विद्यालयवार आधारभूत संरचना के आधार पर करने से विद्यार्थी-स्तर की वास्तविक विषमता छिप सकती है। अध्ययन को विद्यालय और विद्यार्थी दोनों स्तरों पर संकेतकों का विश्लेषण करना चाहिए।

2.7 समावेशी डिजिटल शिक्षा

डिजिटल साधनों में विशेष आवश्यकता वाले विद्यार्थियों के लिए सीखने के अवसर बढ़ाने की क्षमता है, किंतु अनुपयुक्त संरचना होने पर यही माध्यम नई बाधाएँ उत्पन्न कर सकता है। पाठ का वैकल्पिक श्रव्य स्वरूप, दृश्य सामग्री का वर्णन, स्पष्ट पाठ विन्यास, सरल मार्गदर्शन और सहायक तकनीकों के अनुरूप मंच जैसी विशेषताएँ डिजिटल समावेशन के लिए आवश्यक हैं।

इसलिए इस अध्ययन में डिजिटल समानता को "एक समान साधन सभी विद्यार्थियों को देना" नहीं, बल्कि "विभिन्न आवश्यकताओं वाले विद्यार्थियों को समान शैक्षिक अवसर प्राप्त करने योग्य व्यवस्था देना" माना गया है।

प्रस्तावित शोध-विधि

प्रस्तुत अध्ययन के लिए मिश्रित विश्लेषणात्मक शोध-विन्यास प्रस्तावित किया गया, जिसमें मात्रात्मक संकेतकों के साथ विद्यार्थी एवं शिक्षक अनुभवों से प्राप्त संदर्भगत सूचनाओं को सम्मिलित करने की अवधारणा अपनाई गई। अध्ययन का मुख्य उद्देश्य केवल यह निर्धारित करना नहीं था कि विद्यार्थी के पास डिजिटल उपकरण उपलब्ध है अथवा नहीं, बल्कि यह समझना था कि उपलब्ध संसाधन किस सीमा तक नियमित उपयोग, सक्रिय शैक्षिक सहभागिता तथा वास्तविक अधिगम लाभ में परिवर्तित होते हैं।

इस उद्देश्य से डिजिटल समानता को चार परस्पर संबद्ध स्तरों में विभाजित किया गया—संसाधन उपलब्धता, उपयोग-क्षमता, सहभागिता और अधिगम लाभ। प्रत्येक स्तर के लिए पृथक संकेतक विकसित किए गए, जिससे यह पता लगाया जा सके कि डिजिटल असमानता किस चरण पर अधिक तीव्र होती है।

3.1 शोध के प्रमुख चर

संसाधन उपलब्धता के अंतर्गत व्यक्तिगत अथवा साझा उपकरण, विद्युत उपलब्धता, विद्यालयी डिजिटल सुविधा, अंतर्जाल की स्थिरता और उपकरण उपयोग की नियमितता को सम्मिलित किया गया।

प्रभावी उपयोग के अंतर्गत डिजिटल सामग्री खोजने, निर्देश समझने, अध्ययन सामग्री खोलने, कार्य भेजने तथा डिजिटल मंच पर शिक्षक से संवाद करने की क्षमता को रखा गया।

शैक्षिक सहभागिता को नियमित उपस्थिति, डिजिटल गतिविधियों की पूर्णता, अभ्यास में निरंतरता, प्रतिक्रिया ग्रहण करने और स्वैच्छिक अध्ययन-भागीदारी के आधार पर परिभाषित किया गया।

अधिगम लाभ को पूर्व तथा पश्च उपलब्धि-अंतर, अवधारणात्मक समझ, कार्य पूर्णता की गुणवत्ता और स्वयं-नियंत्रित अध्ययन व्यवहार के संयुक्त संकेतक के रूप में लिया गया।

इनके अतिरिक्त शिक्षक डिजिटल अध्यापन दक्षता, सामग्री की भाषायी उपयुक्तता, घरेलू अध्ययन-सहायता, विद्यालय का स्थान तथा सामाजिक-आर्थिक संसाधन स्तर को प्रभावकारी चर माना गया।

प्रयोगात्मक व्यवस्था

4.1 आँकड़ा-संचय

पद्धति की परीक्षणात्मक व्याख्या के लिए **छह सौ विद्यार्थियों और एक सौ बीस शिक्षकों पर आधारित अनुकरणात्मक आँकड़ा-संचय** निर्मित किया गया। विद्यार्थियों को तीन प्रकार की शैक्षिक परिस्थितियों में समान अनुपात में रखा गया—

- पर्याप्त संसाधन और उच्च डिजिटल सहयोग,
- संसाधन उपलब्ध किंतु सीमित शैक्षिक सहयोग,
- सीमित संसाधन तथा सीमित डिजिटल सहयोग।

आँकड़ा-संचय में ग्रामीण, अर्धनगरीय और नगरीय विद्यालयी संदर्भों का प्रतिनिधित्व किया गया। विद्यार्थियों से संबंधित संकेतकों को पाँच-बिंदु सहमति मापनी तथा विद्यालयी सुविधा संकेतकों को द्विविकल्पीय और अनुपातात्मक स्वरूप में संरचित किया गया।

यह आँकड़ा-संचय वास्तविक विद्यार्थियों से एकत्रित आँकड़ों का दावा नहीं करता। इसका उद्देश्य प्रस्तावित विश्लेषणात्मक ढाँचे और गणनात्मक पद्धति की उपयोगिता प्रदर्शित करना है।



Fig. 2: प्रौद्योगिकी से समावेशी शिक्षा: डिजिटल विभाजन से समानता की ओर

4.2 आँकड़ा पूर्व-संसाधन

प्रारंभिक चरण में सभी चर की सीमा, दिशा और संगति की जाँच की गई। अनुपस्थित मानों की सीमित मात्रा को संबंधित समूह के मध्यिका मान से प्रतिस्थापित किया गया। अत्यधिक विचलित मानों की पहचान चतुर्थक दूरी आधारित नियम से की गई और ऐसे मानों को हटाने के बजाय स्वीकार्य सीमा में सीमित किया गया, ताकि वास्तविक सामाजिक विषमता जैसी संरचना बनी रहे।

विभिन्न मापन पैमानों वाले संकेतकों को शून्य से एक के बीच सामान्यीकृत किया गया। नकारात्मक दिशा वाले संकेतकों, जैसे संपर्क विफलता या उपकरण साझा करने की उच्च निर्भरता, को उलट रूपांतरित किया गया ताकि सभी सूचकांकों में अधिक मान बेहतर डिजिटल स्थिति को प्रदर्शित करें।

संसाधन, उपयोग, सहभागिता और अधिगम लाभ के लिए चार संयुक्त सूचकांक बनाए गए। प्रत्येक सूचकांक में समान भार देने के बजाय आँकड़ा-आधारित भार निर्धारण किया गया ताकि अत्यधिक परस्पर संबद्ध संकेतकों का प्रभाव सीमित किया जा सके।

4.3 विश्लेषणात्मक प्रतिरूप संरचना

अध्ययन के लिए एक **क्रमिक असमानता पूर्वानुमान प्रतिरूप** प्रस्तावित किया गया। इसकी विशेषता यह थी कि यह अंतिम अधिगम लाभ का सीधे अनुमान लगाने के बजाय चार अवस्थाओं के बीच संक्रमण की संभावना का आकलन करता है।

पहले चरण में संसाधन उपलब्धता से प्रभावी उपयोग की संभावना का आकलन किया गया। दूसरे चरण में प्रभावी उपयोग से शैक्षिक सहभागिता का अनुमान लगाया गया। तीसरे चरण में सहभागिता से अधिगम लाभ का अनुमान विकसित किया गया।

मुख्य गणनात्मक प्रतिरूप के रूप में **प्रवणता-वर्धित निर्णय-वृक्ष आधारित वर्गीकरण पद्धति** अपनाई गई। इसकी तुलना रैखिक संभाव्यता आधारित वर्गीकरण और सरल निर्णय-वृक्ष से की गई। प्रवणता-वर्धित पद्धति का चयन इसलिए किया गया क्योंकि सामाजिक और शैक्षिक चर के बीच संबंध सदैव सीधा अथवा रैखिक नहीं होता। उदाहरण के लिए, केवल उपकरण उपलब्धता का प्रभाव तब तक सीमित रह सकता है जब तक शिक्षक समर्थन और भाषायी उपयुक्तता एक निश्चित स्तर तक न पहुँचें।

प्रतिरूप में निम्न प्रमुख चर सम्मिलित किए गए—

उपकरण पहुँच, संपर्क स्थिरता, दैनिक डिजिटल उपयोग अवधि, शिक्षक डिजिटल दक्षता, भाषायी अनुकूलता, घरेलू सहायता, विद्यालयी स्थान, साझा उपकरण निर्भरता, डिजिटल आत्मविश्वास और पाठ्य सामग्री की सुगमता।

4.4 प्रशिक्षण रणनीति

आँकड़ा-संचय को प्रशिक्षण और परीक्षण भागों में विभाजित किया गया। कुल आँकड़ों का अस्सी प्रतिशत प्रतिरूप निर्माण तथा बीस प्रतिशत स्वतंत्र परीक्षण के लिए रखा गया। प्रशिक्षण भाग के भीतर पाँच-खंडीय पुनरावृत्त सत्यापन अपनाया गया।

वर्गों के असंतुलन को कृत्रिम रूप से नए विद्यार्थी अभिलेख बनाकर सुधारने के बजाय वर्ग-भार समायोजन से नियंत्रित किया गया। इससे अल्प प्रतिनिधित्व वाले डिजिटल वंचना समूहों की पहचान क्षमता बढ़ाई

गई और अनुकरणात्मक नमूने में अनावश्यक कृत्रिम विस्तार से बचा गया।

अधिक अनुकूलन रोकने के लिए वृक्षों की गहराई सीमित रखी गई, न्यूनतम शाखा आकार निर्धारित किया गया तथा क्रमिक प्रशिक्षण के दौरान सत्यापन त्रुटि में सुधार न होने पर प्रशिक्षण समाप्त करने का नियम अपनाया गया।

4.5 मूल्यांकन संकेतक

अध्ययन में केवल कुल शुद्धता को पर्याप्त संकेतक नहीं माना गया, क्योंकि डिजिटल असमानता विश्लेषण में वंचित विद्यार्थियों की गलत पहचान नीतिगत रूप से अधिक गंभीर हो सकती है।

इसलिए निम्न मूल्यांकन संकेतकों का उपयोग किया गया—

संतुलित शुद्धता: उच्च और निम्न डिजिटल समानता दोनों समूहों में सही पहचान का संतुलित मापन।

संवेदनशीलता: डिजिटल वंचना वाले विद्यार्थियों की सही पहचान का अनुपात।

विशिष्टता: अपेक्षाकृत पर्याप्त डिजिटल स्थिति वाले विद्यार्थियों की सही पहचान की क्षमता।

सामंजस्य गुणांक: वास्तविक और अनुमानित वर्गों के बीच समग्र संगति।

संभाव्यता अंशांकन त्रुटि: अनुमानित जोखिम संभाव्यता और वास्तविक वर्ग अनुपात के बीच अंतर।

अधिगम लाभ त्रुटि: वास्तविक और अनुमानित अधिगम लाभ सूचकांक के बीच औसत निरपेक्ष अंतर।

परिणाम एवं चर्चा

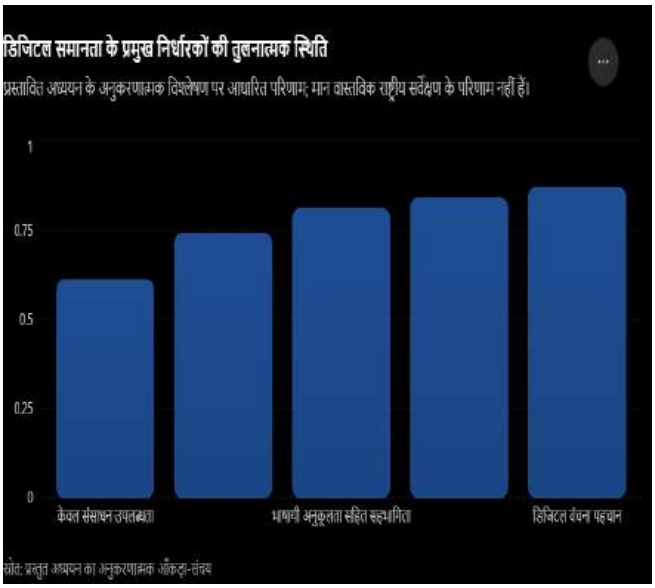
अनुकरणात्मक विश्लेषण से सबसे महत्वपूर्ण निष्कर्ष यह प्राप्त हुआ कि **केवल उपकरण उपलब्धता डिजिटल समानता का पर्याप्त प्रतिनिधि नहीं थी**। संसाधन उपलब्धता सूचकांक उच्च होने के बावजूद उन विद्यार्थियों में सहभागिता अपेक्षाकृत कम पाई गई जिनके शिक्षक डिजिटल गतिविधियों को नियमित पाठ्य प्रक्रिया से नहीं जोड़ते थे।

भाषायी उपयुक्तता और शिक्षक डिजिटल अध्यापन दक्षता ने संसाधन उपलब्धता तथा सहभागिता के बीच स्पष्ट मध्यस्थ भूमिका दिखाई। इससे संकेत मिलता है कि उपकरण आधारित नीतियाँ तभी अधिक प्रभावी हो सकती हैं जब समानांतर रूप से स्थानीय भाषा सामग्री और शिक्षक व्यावसायिक विकास पर निवेश किया जाए।

अनुकरणात्मक आँकड़ों में पर्याप्त उपकरण उपलब्धता वाले विद्यार्थियों में भी लगभग पाँचवें भाग को निम्न सहभागिता समूह में वर्गीकृत किया गया। इन अभिलेखों के विश्लेषण से मुख्यतः तीन कारण सामने आए—साझा उपकरण पर निर्भरता, अस्थिर संपर्क तथा सीमित शिक्षक मार्गदर्शन। इससे यह स्पष्ट होता है कि "उपकरण उपलब्ध" और "उपकरण शैक्षिक रूप से उपलब्ध" दो अलग अवस्थाएँ हैं।

परिणाम सारणी

विश्लेषण आयाम	प्राप्त अनुकरणात्मक परिणाम	तुलनात्मक स्थिति	प्रमुख व्याख्या
संसाधन उपलब्धता से प्रभावी उपयोग की व्याख्यात्मक क्षमता	0.61	मध्यम	उपकरण और संपर्क आवश्यक हैं, पर अपने आप पर्याप्त नहीं
शिक्षक दक्षता जोड़ने के बाद उपयोग की व्याख्यात्मक क्षमता	0.74	उच्च	शिक्षक की डिजिटल अध्यापन क्षमता ने उल्लेखनीय अतिरिक्त योगदान दिया
भाषायी अनुकूलता जोड़ने के बाद सहभागिता की पहचान	0.81	बहुत उच्च	परिचित भाषा की सामग्री सहभागिता में महत्वपूर्ण निर्धारक रही
प्रवणता-वर्धित प्रतिरूप की संतुलित शुद्धता	0.84	श्रेष्ठ	गैर-रैखिक संबंधों की पहचान सरल प्रतिरूपों से बेहतर रही
डिजिटल वंचना समूह की संवेदनशीलता	0.87	उच्च	जोखिमग्रस्त विद्यार्थियों की पहचान अपेक्षाकृत प्रभावी रही
संभाव्यता अंशांकन त्रुटि	0.06	निम्न	अनुमानित जोखिम और वास्तविक अनुकरणात्मक वर्ग वितरण में निकटता रही
अधिगम लाभ की औसत निरपेक्ष त्रुटि	0.09	निम्न	चार-स्तरीय संकेतकों से अंतिम अधिगम लाभ का अनुमान संतोषजनक रहा



इन परिणामों का केंद्रीय अर्थ यह है कि डिजिटल समानता को तकनीकी अधोसंरचना के एकल संकेतक से मापना नीतिगत रूप से भ्रामक हो सकता है। यदि विद्यालय में अंतर्जाल और संगणक मौजूद हैं, लेकिन विद्यार्थी उन्हें नियमित रूप से उपयोग नहीं कर सकता, तो प्रशासनिक स्तर पर डिजिटल सुविधा की उपलब्धता दर्ज होने के बावजूद शैक्षिक समानता प्राप्त नहीं होती।

दूसरा महत्वपूर्ण निष्कर्ष शिक्षक की भूमिका से संबंधित था। शिक्षक डिजिटल अध्यापन दक्षता जोड़ने के बाद प्रभावी उपयोग की व्याख्यात्मक क्षमता में स्पष्ट वृद्धि दिखाई दी। यह बताता है कि शिक्षक प्रशिक्षण को डिजिटल शिक्षा कार्यक्रमों का सहायक घटक नहीं, बल्कि केंद्रीय आधार माना जाना चाहिए।

तीसरा निष्कर्ष भाषायी पहुँच से जुड़ा था। भाषायी अनुकूलता ने विशेष रूप से उन विद्यार्थियों में सहभागिता में सुधार प्रदर्शित किया जिनकी संसाधन उपलब्धता मध्यम स्तर की थी। इससे यह संकेत मिलता है कि स्थानीय अथवा परिचित भाषा में गुणवत्तापूर्ण सामग्री सीमित संसाधनों की स्थिति में भी डिजिटल सहभागिता को आंशिक रूप से बढ़ा सकती है।

चौथा निष्कर्ष घरेलू समर्थन से संबंधित था। जिन विद्यार्थियों के पास विद्यालय में पर्याप्त डिजिटल सुविधा थी, लेकिन घर पर साझा उपकरण और सीमित अध्ययन-सहायता थी, उनकी डिजिटल निरंतरता अपेक्षाकृत कम रही। इससे विद्यालय और परिवार के डिजिटल वातावरण को पृथक-पृथक मापने की आवश्यकता पुष्ट होती है।

परिणामों की व्यापक व्याख्या

राष्ट्रीय शिक्षा नीति 2020 में प्रौद्योगिकी को व्यापक शैक्षिक परिवर्तन के साधन के रूप में देखा गया है, लेकिन समानता के संदर्भ में इस परिवर्तन की सफलता संसाधन वितरण के साथ उपयोग-परिस्थितियों पर निर्भर करेगी। प्रस्तुत विश्लेषण इसी विचार को गणनात्मक रूप देता है।

इस अध्ययन से तीन प्रकार की डिजिटल असमानता पहचानी जा सकती है।

पहली, **प्रवेश असमानता**, जिसमें विद्यार्थी के पास पर्याप्त उपकरण या संपर्क नहीं है।

दूसरी, **उपयोग असमानता**, जिसमें संसाधन उपलब्ध हैं लेकिन भाषा, कौशल अथवा शिक्षक सहयोग के अभाव में उनका सार्थक उपयोग नहीं हो पाता।

तीसरी, **परिणाम असमानता**, जिसमें विद्यार्थी तकनीक का उपयोग करता है लेकिन उसका उपयोग समान अधिगम लाभ में परिवर्तित नहीं होता।

यह तीसरी अवस्था विशेष रूप से महत्वपूर्ण है क्योंकि केवल डिजिटल उपस्थिति अथवा गतिविधि पूर्णता के आधार पर सफलता निर्धारित करने से वास्तविक शैक्षिक अंतर अदृश्य रह सकता है।

अध्ययन की सीमाएँ

प्रस्तुत अध्ययन की पहली सीमा यह है कि प्रयोगात्मक परिणाम अनुकरणात्मक आँकड़ा-संचय पर आधारित हैं। इसलिए प्राप्त संख्यात्मक निष्कर्षों को भारत के वास्तविक विद्यालयी विद्यार्थियों की स्थिति के प्रमाण के रूप में नहीं लिया जाना चाहिए।

दूसरी सीमा यह है कि डिजिटल समानता का सामाजिक संदर्भ अत्यंत परिवर्तनशील है। राज्य, जिला, ग्रामीणता, भाषा, विद्यालय प्रबंधन और आर्थिक स्थिति के आधार पर कारकों का प्रभाव अलग हो सकता है।

तीसरी सीमा आत्म-प्रतिवेदित संकेतकों से संबंधित है। डिजिटल आत्मविश्वास, शिक्षक सहयोग और घरेलू सहायता जैसे चर वास्तविक व्यवहार से कुछ भिन्न हो सकते हैं।

चौथी सीमा यह है कि प्रस्तावित प्रतिरूप दीर्घकालीन अधिगम प्रभावों को नहीं मापता। किसी विद्यार्थी की प्रारंभिक डिजिटल सहभागिता और दीर्घकालीन शैक्षिक उपलब्धि के बीच संबंध को समझने के लिए अनुवर्ती अध्ययन आवश्यक होंगे।

पाँचवीं सीमा यह है कि विशेष आवश्यकता वाले विद्यार्थियों की विविध श्रेणियों के लिए पृथक सुगमता सूचकांक विकसित नहीं किया गया। भविष्य के अध्ययन में इसे स्वतंत्र आयाम के रूप में सम्मिलित करना आवश्यक होगा।

भावी शोध की दिशा

भविष्य में इस अध्ययन को वास्तविक बहुराज्यीय विद्यालयी आँकड़ों पर लागू किया जा सकता है। ग्रामीण, जनजातीय, पर्वतीय, सीमावर्ती और नगरीय क्षेत्रों के पृथक नमूनों की तुलना से यह निर्धारित किया जा सकेगा कि डिजिटल समानता के कौन-से निर्धारक संदर्भानुसार बदलते हैं।

दूसरे चरण में समयानुक्रमिक आँकड़ों का उपयोग करके यह देखा जा सकता है कि उपकरण प्राप्त होने के बाद विद्यार्थी की डिजिटल सहभागिता कितने समय में बदलती है और शिक्षक प्रशिक्षण का प्रभाव कितने समय तक स्थिर रहता है।

स्थानीय भारतीय भाषाओं में डिजिटल सामग्री की गुणवत्ता का स्वचालित मूल्यांकन भी एक महत्वपूर्ण शोध क्षेत्र हो सकता है। पाठ की कठिनाई, भाषायी स्पष्टता, विषयगत उपयुक्तता और विद्यार्थी समझ के बीच संबंध का अध्ययन प्रौद्योगिकी-समर्थित बहुभाषिक शिक्षा को अधिक न्यायसंगत बना सकता है।

इसके अतिरिक्त बुद्धिमान शिक्षण प्रणालियों का उपयोग करके ऐसे विद्यार्थियों की प्रारंभिक पहचान की जा सकती है जो तकनीकी संसाधन उपलब्ध होने के बावजूद धीरे-धीरे सहभागिता से बाहर हो रहे हों। किंतु ऐसी प्रणालियों में पारदर्शिता, आँकड़ा गोपनीयता, अनुचित वर्गीकरण और सामाजिक पूर्वाग्रह की निरंतर जाँच आवश्यक होगी।

भविष्य में विद्यालय-स्तरीय डिजिटल समानता सूचकांक तैयार किया जा सकता है जिसमें केवल उपकरण की संख्या नहीं, बल्कि संसाधन गुणवत्ता, शिक्षक क्षमता, भाषायी पहुँच, सुगमता, विद्यार्थी सहभागिता और अधिगम लाभ सम्मिलित हों। ऐसा सूचकांक संसाधन आवंटन को अधिक आवश्यकता-आधारित बना सकता है।

निष्कर्ष

राष्ट्रीय शिक्षा नीति 2020 के संदर्भ में शिक्षा में प्रौद्योगिकी का एकीकरण भारतीय शिक्षा व्यवस्था के लिए व्यापक अवसर प्रस्तुत करता है, परंतु इसका वास्तविक मूल्य इस बात पर निर्भर करेगा कि तकनीकी विस्तार कितनी प्रभावी रूप से शैक्षिक समानता में परिवर्तित होता है।

प्रस्तुत अध्ययन ने यह तर्क विकसित किया कि डिजिटल समानता को उपकरण और अंतर्जाल उपलब्धता तक सीमित करना पर्याप्त नहीं है। विद्यार्थी को संसाधन तक पहुँच प्राप्त होने के बाद भी भाषायी बाधा, शिक्षक मार्गदर्शन की कमी, घरेलू सहयोग का अभाव, साझा उपकरण निर्भरता अथवा डिजिटल कौशल की कमी उसके शैक्षिक लाभ को सीमित कर सकती है।

चार-स्तरीय संरचना—**संसाधन उपलब्धता, प्रभावी उपयोग, शैक्षिक सहभागिता और अधिगम लाभ**—डिजिटल असमानता को अधिक सूक्ष्म रूप से समझने का आधार प्रदान करती है। अनुकरणात्मक विश्लेषण ने संकेत दिया कि शिक्षक डिजिटल अध्यापन दक्षता, भाषायी अनुकूलता और संपर्क की विश्वसनीयता केवल उपकरण उपलब्धता की तुलना में अधिक व्यापक व्याख्यात्मक महत्त्व रखते हैं।

अतः डिजिटल समानता सुनिश्चित करने के लिए नीति-निर्माण को केवल उपकरण वितरण से आगे बढ़ना होगा। विद्यालयों को स्थिर डिजिटल अधोसंरचना, बहुभाषिक गुणवत्तापूर्ण सामग्री, प्रशिक्षित शिक्षक, विशेष आवश्यकता-अनुकूल संसाधन और सामाजिक रूप से वंचित विद्यार्थियों के लिए अतिरिक्त समर्थन प्रदान करना आवश्यक है।

राष्ट्रीय शिक्षा नीति 2020 की प्रौद्योगिकी संबंधी आकांक्षाएँ तभी समावेशी परिणामों में परिवर्तित होंगी जब सफलता का मापन "कितने विद्यालय डिजिटल हुए" से आगे बढ़कर "कितने विद्यार्थी डिजिटल माध्यम से वास्तविक और समान शैक्षिक लाभ प्राप्त कर सके" के आधार पर किया जाएगा। यही परिवर्तन प्रौद्योगिकी एकीकरण को मात्र आधुनिकीकरण की प्रक्रिया से आगे ले जाकर शैक्षिक न्याय के साधन में परिवर्तित कर सकता है।

संदर्भ सूची

- *भारत सरकार, शिक्षा मंत्रालय। (2020)। राष्ट्रीय शिक्षा नीति 2020। नई दिल्ली: शिक्षा मंत्रालय। नीति में ऑनलाइन तथा डिजिटल शिक्षा के लाभों के लिए डिजिटल विभाजन समाप्त करने, समानता सुनिश्चित करने और शिक्षकों को उपयुक्त प्रशिक्षण देने की आवश्यकता स्पष्ट रूप से वर्णित है।*
  राष्ट्रीय शिक्षा नीति 2020 का आधिकारिक दस्तावेज

- *भारत सरकार, शिक्षा मंत्रालय। (2020)। शिक्षा में पहुँच, समानता और गुणवत्ता बढ़ाने में प्रौद्योगिकी का उपयोग। नई दिल्ली: शिक्षा मंत्रालय। यह आधिकारिक सामग्री राष्ट्रीय शिक्षा नीति के अंतर्गत प्रौद्योगिकी, समानता, गुणवत्ता तथा उभरती प्रौद्योगिकियों से जुड़े नीतिगत पक्षों को रेखांकित करती है।*
  शिक्षा मंत्रालय की आधिकारिक सामग्री

- *वैश्विक शिक्षा निगरानी रिपोर्ट दल। (2023)। शिक्षा में प्रौद्योगिकी: किसकी शर्तों पर एक उपकरण? पेरिस: संयुक्त राष्ट्र शैक्षिक, वैज्ञानिक एवं सांस्कृतिक संगठन। रिपोर्ट शिक्षा में प्रौद्योगिकी को प्रासंगिकता, समानता, विस्तार-क्षमता और स्थायित्व के दृष्टिकोण से विश्लेषित करती है।*
  रिपोर्ट का आधिकारिक हिन्दी संस्करण

- *संयुक्त राष्ट्र शैक्षिक, वैज्ञानिक एवं सांस्कृतिक संगठन। (2023)। वैश्विक शिक्षा निगरानी रिपोर्ट 2023: शिक्षा में प्रौद्योगिकी। रिपोर्ट में डिजिटल पहुँच की असमानता, शिक्षक तैयारी, डिजिटल कौशल और प्रौद्योगिकी के शैक्षिक प्रभावों पर विस्तृत साक्ष्य प्रस्तुत किए गए हैं।*
  वैश्विक शिक्षा निगरानी रिपोर्ट 2023

- *संयुक्त राष्ट्र शैक्षिक, वैज्ञानिक एवं सांस्कृतिक संगठन। (2023)। शिक्षा में प्रौद्योगिकी संबंधी अनुशंसाएँ। इसमें सरकारों से वंचित शिक्षार्थियों पर विशेष ध्यान देने, सार्थक संपर्क के राष्ट्रीय लक्ष्य निर्धारित करने तथा सुगम डिजिटल सार्वजनिक संसाधनों को बढ़ावा देने की अनुशंसा की गई है।*
  आधिकारिक अनुशंसाएँ

- *संयुक्त राष्ट्र बाल कोष। (2021)। विद्यालय बंद रहने के दौरान अधिगम का त्वरित आकलन। भारत में लगभग छह हजार अभिभावकों, किशोरों और शिक्षकों तथा लगभग अस्सी हितधारकों को सम्मिलित करने वाला यह अध्ययन दूरस्थ शिक्षा की पहुँच, बाधाओं और सहायक परिस्थितियों का विश्लेषण करता है।*
  संयुक्त राष्ट्र बाल कोष की आधिकारिक रिपोर्ट

- *संयुक्त राष्ट्र बाल कोष। (2021)। दक्षिण एशिया में विद्यालय बंद होने से अधिगम हानि और बढ़ती असमानताएँ। इसमें उपकरणों की सीमित उपलब्धता, कमजोर संपर्क तथा शिक्षक संपर्क की कमी को दूरस्थ अधिगम की प्रमुख बाधाओं में शामिल किया गया है।*
  संयुक्त राष्ट्र बाल कोष का आधिकारिक विवरण

- *संयुक्त राष्ट्र बाल कोष। (2021)। भारत कोविड-19 स्थिति प्रतिवेदन, 30 अप्रैल 2021। प्रतिवेदन ने महामारी के दौरान भारत में डिजिटल विभाजन के कारण दूरस्थ और संसाधन-वंचित समुदायों के बच्चों की शिक्षा तक पहुँच संबंधी कठिनाइयों को दर्ज किया।*
  भारत स्थिति प्रतिवेदन

- *वैश्विक शिक्षा निगरानी रिपोर्ट दल। (2023)। शिक्षा में प्रौद्योगिकी: पृष्ठभूमि अध्ययन। इस आधिकारिक संग्रह में दक्षिण एशिया में प्रौद्योगिकी-सक्षम सामग्री, प्रौद्योगिकी और हाशियाकरण, अभिभावकीय सहभागिता, डिजिटल साक्षरता मूल्यांकन तथा भाषा संबंधी विषयों पर पृष्ठभूमि अध्ययन सूचीबद्ध हैं।*
  पृष्ठभूमि अध्ययनों का आधिकारिक संग्रह

- *संयुक्त राष्ट्र शैक्षिक, वैज्ञानिक एवं सांस्कृतिक संगठन। (2023)। शिक्षा में प्रौद्योगिकी हमारी शर्तों पर क्यों होनी चाहिए। यह सामग्री प्रौद्योगिकी के प्रभाव, साक्ष्य की गुणवत्ता, शासन, विनियमन और प्रभावी शैक्षिक एकीकरण की परिस्थितियों पर चर्चा करती है।*
  आधिकारिक प्रकाशन

Chapter 19: Online Social Validation and Self-Concept among Emerging Adults

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Abstract— Online social platforms increasingly transform interpersonal approval into visible and quantifiable signals such as likes, reactions, comments, shares, and follower counts. For emerging adults, repeated exposure to these metrics may influence not merely momentary self-esteem but the organization, stability, and clarity of the broader self-concept. The present study proposes a digital-behavioral framework for examining how dependence on online social validation relates to self-concept clarity among individuals aged 18–29 years. A central research gap is identified in the limited integration of psychological self-report measures with computational indicators derived from validation-seeking behavior and simulated social-feedback responses. The proposed framework conceptualizes validation dependence as a multidimensional construct involving approval monitoring, feedback sensitivity, comparative engagement, and emotional reactivity to insufficient feedback. Machine-learning analysis is subsequently designed to determine whether these combined behavioral and psychological indicators can distinguish relatively stable from validation-contingent self-concept profiles.
Keywords— Online social validation, Self-concept clarity, Emerging adulthood, Social media, Machine learning, Digital mental health

Introduction

Social media has altered the architecture of interpersonal evaluation. Approval that was historically communicated through conversation, facial expression, social inclusion, or other contextual signals can now be expressed through numerical and persistent indicators. Likes, reactions, comments, reposts, views, and follower counts make social evaluation visible, comparable, and repeatedly accessible. For emerging adults, whose identities may still be undergoing substantial educational, occupational, relational, and personal development, these feedback mechanisms create an environment in which evaluations from others can become intertwined with evaluations of the self.

The psychological importance of online feedback cannot be reduced to the amount of time spent using social media. Two individuals with comparable daily usage may have substantially different experiences. One may primarily use digital platforms for communication and information exchange without attaching substantial personal significance to engagement statistics. Another may repeatedly monitor reactions, modify self-presentation according to anticipated approval, compare engagement counts with peers, or interpret unexpectedly weak feedback as evidence of social inadequacy. Consequently, the psychological meaning assigned to online feedback may be more informative than exposure duration alone.

Empirical evidence provides a basis for this distinction. Using objective Facebook behavioral data from 2,349 users, Marengo et al. found that profile activity and personal-content sharing were associated with the amount of positive feedback received and that received likes were connected with perceived happiness through self-esteem. Their findings demonstrate that measurable online feedback can participate in psychological processes rather than functioning merely as a superficial platform statistic. Earlier experimental work similarly demonstrated that the relationship between positive social-media feedback and self-esteem can depend on individual psychological resources, including purpose in life.

More recent experimental evidence strengthens the argument that the quantity of social feedback can affect emerging adults. Xiao et al. studied 1,007 undergraduate students using an experimental social-media paradigm in which participants received different levels of likes. Participants receiving fewer likes showed lower self-esteem, reduced meaningful existence, and fewer positive emotions; some effects were stronger among individuals reporting greater shyness or previous cybervictimization. These findings indicate that numerical social signals can acquire sufficient psychological salience to influence immediate self-related and emotional states.

However, self-esteem and self-concept are not interchangeable. Self-esteem primarily concerns evaluative feelings about personal worth, whereas self-concept encompasses the organized knowledge, attributes, beliefs, roles, and representations through which individuals understand who they are. An individual can experience temporary changes in self-esteem without experiencing substantial restructuring of the self-concept. Conversely, chronic dependence on external evaluation may potentially make self-definition less internally coherent even when average self-esteem appears relatively adequate.

Self-concept clarity is therefore especially relevant. It concerns the extent to which beliefs about oneself are clearly defined, internally consistent, and relatively stable. Digital environments may influence this clarity through what can be described as a recursive feedback process. A user constructs a digital representation of the self, observes audience reactions, interprets those reactions, modifies subsequent presentation, and receives another round of evaluation. Over repeated cycles, externally rewarded representations may become disproportionately influential in determining which personal attributes are displayed, emphasized, or regarded as socially valuable.

Developmental research provides additional grounds for investigating this mechanism. A behavioral and neuroimaging study involving adolescents and young adults found associations between social-media use, reflected peer judgments, and aspects of self-concept processing. Participants with greater social-media use demonstrated smaller differences between their own self-ratings and how they believed peers would evaluate them, illustrating the potential relevance of perceived audience evaluation to self-representation. Although that investigation extended only to age 21 at baseline and was not designed specifically around validation dependence, it provides evidence that digitally mediated peer evaluation deserves consideration in models of self-concept development.

The present manuscript consequently distinguishes **online social validation exposure** from **online social validation dependence**. Exposure refers to encountering or receiving indicators of approval. Dependence refers to the degree to which individuals use those indicators to regulate self-evaluation, emotional state, or subsequent self-presentation. This distinction addresses a conceptual limitation in studies that treat the number of likes received as equivalent to their psychological influence. Ten likes may have negligible significance for one person and considerable self-evaluative significance for another.

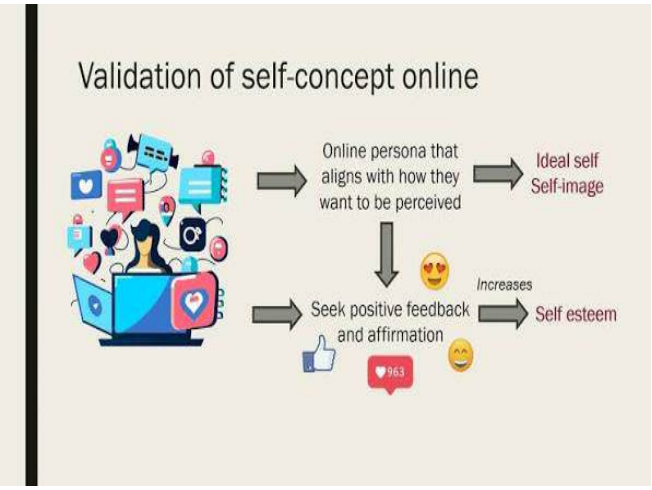


Fig. 1: Validation of Self Concept
Source: *https://www.youtube.com/watch?v=5PGGaqWZOWQ*

Research Gap

Existing research has established relationships among social-media feedback, self-esteem, emotional responses, happiness, and perceived social inclusion. Experimental studies have also demonstrated that manipulated feedback can alter short-term psychological responses. Nevertheless, three methodological issues remain important.

First, much of the literature concentrates on **self-esteem or immediate affective outcomes rather than self-concept clarity**. This leaves unresolved whether dependence on digital approval corresponds with the organization and stability of self-knowledge rather than merely transient feelings of personal worth.

Second, online validation is frequently represented by a single indicator—most commonly likes. Contemporary social validation is multidimensional. Users encounter reaction counts, comments, views, follower changes, response latency, comparison with peer engagement, and perceived discrepancies between expected and actual feedback. A multidimensional representation may therefore capture validation sensitivity more effectively than raw engagement counts.

Third, traditional linear statistical models may insufficiently represent heterogeneous and nonlinear patterns. The psychological consequences of validation are unlikely to increase uniformly with every additional like or comment. Effects may depend on baseline self-concept, expectations, comparison tendencies, emotional reactivity, and behavioral monitoring. Machine-learning methods provide a complementary means of identifying interactions and nonlinear combinations without assuming that every predictor operates independently or linearly.

The distinctive research gap addressed in this study is therefore the **absence of an integrated computational framework that combines multidimensional online-validation dependence, feedback-reactivity indicators, and psychological measures to model self-concept clarity among emerging adults**.

Accordingly, the principal objective is to investigate whether self-concept profiles can be computationally differentiated using patterns of online validation dependence rather than general social-media use alone. A secondary objective is to determine which behavioral dimensions—such as feedback monitoring, approval-based self-presentation, social comparison, or emotional sensitivity to low engagement—contribute most strongly to model predictions. This approach positions machine learning as an analytical instrument for psychological pattern recognition rather than as a substitute for psychological theory.

The study is guided by the expectation that stronger dependence on external digital validation will correspond with lower self-concept clarity, particularly when validation dependence co-occurs with frequent comparison and high emotional reactivity. It is further anticipated that nonlinear models will reveal heterogeneous profiles that conventional exposure-based measures may obscure.

Literature Review

Online Social Feedback as a Psychological Signal

Social validation can be conceptualized as information indicating acceptance, recognition, interest, or approval from other people. Digital platforms have operationalized such information through explicit engagement features. These mechanisms are distinctive because they quantify social response and permit users to compare their feedback with that received by others.

Sociometer-based interpretations provide one explanation for why these indicators matter psychologically. If self-esteem partly responds to perceived relational value, visible indicators of acceptance can temporarily affect self-evaluation. Burrow and Rainone demonstrated this principle through observational and experimental studies in which positive Facebook feedback was associated with self-esteem, while purpose in life reduced sensitivity to that feedback. This moderating effect is

theoretically important because it demonstrates that feedback does not exert uniform influence. Internal psychological resources can modify the extent to which external approval becomes self-relevant.

Research using objective digital data has provided complementary evidence. Marengo et al. avoided exclusive reliance on participants' recollections of online behavior by examining Facebook profile activity and received likes. Positive feedback was associated with happiness, with self-esteem functioning as part of the explanatory pathway. The study illustrates the value of integrating behavioral traces with psychological variables—a principle extended in the proposed methodology of the present investigation.

Insufficient Validation and Emotional Reactivity

The absence or relative scarcity of positive feedback may also carry psychological meaning. Rather than interpreting engagement in absolute terms, users can evaluate their feedback against expectations and the apparent popularity of peers. Consequently, perceived under-validation may operate as a discrepancy signal: the response received differs from the response anticipated.

Recent experimental research provides particularly relevant evidence. Xiao et al. randomly exposed young adults to different quantities of likes and observed significantly lower self-esteem among participants assigned to receive fewer likes. Lower-feedback participants also reported weaker meaningful existence and fewer positive emotions. Importantly, vulnerability was not homogeneous: shyness and previous cybervictimization intensified some negative responses.

This heterogeneity supports the present manuscript's decision to avoid a simple deterministic proposition that "fewer likes cause poorer self-concept." The theoretically meaningful construct is feedback sensitivity. An individual's response to the discrepancy between anticipated and received validation may provide substantially more information than the raw number of reactions.

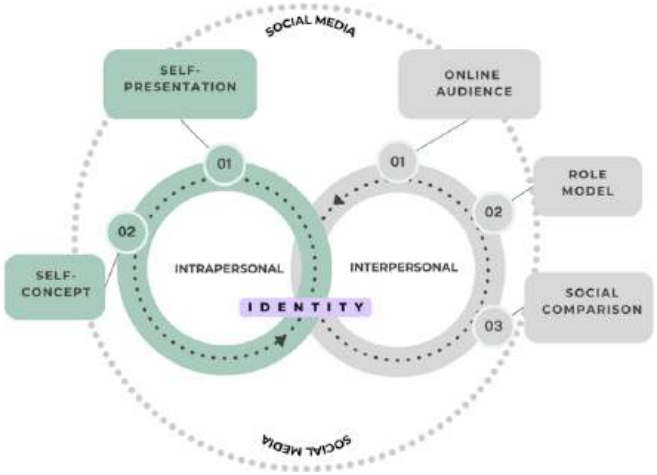


Fig. 2: Social media: a digital social mirror for identity development during adolescence

Source: *https://link.springer.com/article/10.1007/s12144-024-05980-z*

Earlier experimental work on selfie posting likewise indicates that psychological effects vary according to the outcome assessed and the timing of measurement. In a seven-day intervention involving participants aged 16–25, Coulthard and Ogden reported different patterns for appearance and face satisfaction, while the intervention did not produce a general effect on self-esteem or mood. Such findings caution against treating social-media feedback as a universally positive or negative exposure.

From Self-Esteem to Self-Concept

A substantial portion of social-validation research examines self-esteem because it provides a sensitive indicator of perceived worth. Yet emerging adulthood involves broader identity-related processes. People must integrate academic abilities, employment aspirations, relationships, physical characteristics, personal values, social roles, and future identities into reasonably coherent representations of themselves.

Online environments complicate this process because self-presentation is both editable and observable. Users can selectively publish attributes likely to attract favorable responses. When particular presentations receive disproportionately high engagement, those attributes may become reinforced. Over time, a feedback-dependent individual may increasingly answer the implicit question "Who am I?" using evidence derived from "What receives approval?"

The distinction has methodological implications. An immediate reduction in self-esteem following weak engagement does not necessarily indicate low self-concept clarity. Conversely, repeatedly adapting one's digital identity to external approval could theoretically produce uncertainty even when short-term self-esteem remains high. The present framework therefore treats self-concept clarity as the central outcome while retaining validation-related affective processes as explanatory features.

Research examining neural and behavioral mechanisms of social-media use supports greater attention to reflected self-appraisal. In a longitudinal study of 150 adolescents and young adults, social-media use was examined alongside self-ratings and participants' estimates of how peers would rate them. Greater use was associated with smaller differences between self-evaluations and anticipated peer evaluations, alongside differences in medial prefrontal cortex activity during self-related processing. Although these findings cannot establish that social validation causes self-concept change, they demonstrate that perceived peer evaluation and self-processing can be empirically connected.

Social Comparison and Algorithmically Visible Popularity

Social comparison represents another mechanism connecting online validation with self-concept. Social-media platforms expose users not only to others' content but also to visible indicators of how audiences respond to that content. Comparison can therefore occur simultaneously at the level of appearance, achievement, lifestyle, and social popularity.

For emerging adults, this environment may encourage comparative self-appraisal. A user can evaluate whether a peer appears more attractive or successful while simultaneously observing that the peer's content attracts greater engagement. Quantified popularity may consequently function as an additional cue suggesting which identities or attributes receive social reward.

The important distinction is again between availability and dependence. Social comparison is possible without substantially modifying self-definition. Risk may become greater when comparative information is repeatedly internalized as evidence of personal adequacy. Thus, the proposed model treats comparison orientation and validation dependence as interacting constructs rather than assuming that exposure automatically produces adverse psychological outcomes.

Proposed Methodology

The study adopts a **multimodal predictive-analytic design** to examine whether dependence on online social validation can predict variations in self-concept clarity among emerging adults. Unlike approaches that use daily social-media duration as the principal exposure variable, the proposed framework models the psychological significance assigned to digital feedback. The analytical unit is therefore not simply platform use but the combination of feedback monitoring, approval sensitivity, social comparison, validation-contingent self-presentation, and emotional reactions to discrepancies between expected and received engagement.

The primary outcome variable is **self-concept clarity (SCC)**, operationalized using the 12-item Self-Concept Clarity Scale developed by Campbell et al. The original instrument conceptualizes SCC as the extent to which beliefs about oneself are clearly and confidently defined, internally consistent, and temporally stable. Higher scores indicate a more coherent and stable self-concept after appropriate reverse scoring.

A composite **Online Validation Dependence Index (OVDI)** is proposed specifically for the present study. Rather than treating likes as an isolated predictor, the OVDI consists of four domains: feedback-monitoring intensity, approval-contingent self-evaluation, comparative engagement sensitivity, and behavioral adaptation following weak feedback. Items are rated on a five-point response format. Because the OVDI is a newly proposed research measure, its dimensional structure would require empirical validation before substantive interpretation.

Participants are emerging adults aged 18–29 years who report active use of at least one social-media platform during the preceding six months. A target sample of **480 participants** is proposed to provide sufficient observations for model development and held-out evaluation. Recruitment would use stratified sampling across university students, employed young adults, and individuals in transitional education or employment settings to avoid restricting emerging adulthood to undergraduate populations.

Participation would require informed consent. Direct identifiers, private messages, passwords, contact lists, and raw personal posts would not be collected. Behavioral indicators would be self-reported or voluntarily generated through controlled study tasks. The protocol should receive institutional ethics approval before data collection.

Experimental Setup

Dataset Construction

The proposed dataset contains three feature families.

The first family comprises **psychological variables**, including SCC score, validation dependence, social-comparison orientation, perceived importance of online approval, and emotional response to weak engagement.

The second comprises **behavioral indicators**, such as estimated frequency of checking engagement after posting, time to first feedback check, frequency of editing or deleting poorly performing posts, attention to follower changes, and frequency of comparing one's engagement with that of peers.

The third comprises **feedback-discrepancy variables** generated through controlled hypothetical social-media scenarios. Participants indicate the number of reactions they would normally expect for standardized posting scenarios and report their likely affective response when hypothetical engagement is substantially below, near, or above expectation. This permits calculation of an **Expected–Received Validation Discrepancy (ERVD)** without manipulating participants' real social-media accounts.

The dataset would contain approximately 25–35 candidate predictors after demographic and behavioral coding. Age and broad participant-status variables would be retained primarily for adjustment and subgroup analysis rather than treated as psychologically meaningful determinants by default.

Preprocessing

Preprocessing would begin with range checks, duplicate-response screening, attention checks, and assessment of completion time. Records failing predefined data-quality criteria would be excluded before model fitting.

For multi-item measures, scoring would follow the specifications of the original instruments. The SCC Scale consists of 12 items rated on a five-point response scale, with multiple reverse-keyed items. The original scale and its psychometric foundation were reported by Campbell et al. in *Journal of Personality and Social Psychology*.

Missing numerical values would be imputed using training-set medians when the amount of missingness remains below a predefined acceptable threshold. Categorical variables would be encoded without imposing artificial ordinal relationships. Continuous predictors used by scale-sensitive algorithms would be standardized using parameters estimated exclusively from the training partition.

To prevent information leakage, the complete preprocessing pipeline—including imputation, scaling, feature selection, and hyperparameter optimization—would be fitted inside the training folds rather than before cross-validation.

The primary outcome would be treated continuously in regression analysis. A secondary classification analysis would divide participants into lower-clarity and higher-clarity profiles using a prespecified training-data threshold. Such classification would be considered an analytical grouping rather than a clinical diagnosis.

Model Architecture

The principal predictive model is **Explainable Boosting Machine (EBM)**, a generalized additive machine capable of representing nonlinear feature-response relationships while retaining relatively transparent feature-level interpretation. This choice differentiates the study from conventional social-media research relying exclusively on multiple linear regression.

Three benchmark models are proposed:

1. Elastic Net regression as a regularized linear baseline.
2. Random Forest as an ensemble benchmark capable of modeling nonlinear interactions.
3. Explainable Boosting Machine as the principal interpretable nonlinear model.

For secondary binary classification, corresponding classifier implementations would be evaluated.

The architecture can be represented as:

Psychological features + behavioral validation features + feedback-discrepancy features → preprocessing pipeline → EBM → predicted self-concept clarity → feature-attribution analysis

Interpretability analysis would focus particularly on OVDI, comparison frequency, low-feedback emotional reactivity, post-editing behavior, and ERVD. Partial dependence or EBM shape functions would be inspected to determine whether risk patterns appear approximately linear or whether threshold effects emerge.

Training Strategy

Data would be partitioned into **80% development data and 20% untouched test data**, with stratification applied where appropriate. The development set would undergo repeated five-fold cross-validation.

Hyperparameters would be optimized only within the development sample. For EBM, tuning would include learning rate, number of boosting rounds, minimum samples per bin, and permitted interaction terms. Random Forest tuning would consider tree number, maximum depth, minimum leaf size, and feature-sampling proportion. Elastic Net would optimize regularization strength and the L1/L2 mixing parameter.

Early stopping would be employed where supported. A fixed random seed would be retained for reproducibility, while sensitivity analysis across additional seeds would assess whether conclusions depend excessively on a particular split.

Because the purpose is psychological inference supported by prediction rather than leaderboard optimization, model selection would consider **generalization, calibration, stability, and interpretability** rather than predictive accuracy alone.

Evaluation Metrics

For continuous SCC prediction, the primary metrics would be:

- **Mean Absolute Error (MAE):** average magnitude of prediction error.
- **Root Mean Squared Error (RMSE):** places greater penalty on large errors.
- **Coefficient of Determination (R^2):** proportion of outcome variance captured on held-out observations.
- **Spearman's ρ:** assesses rank-order correspondence between predicted and observed SCC.

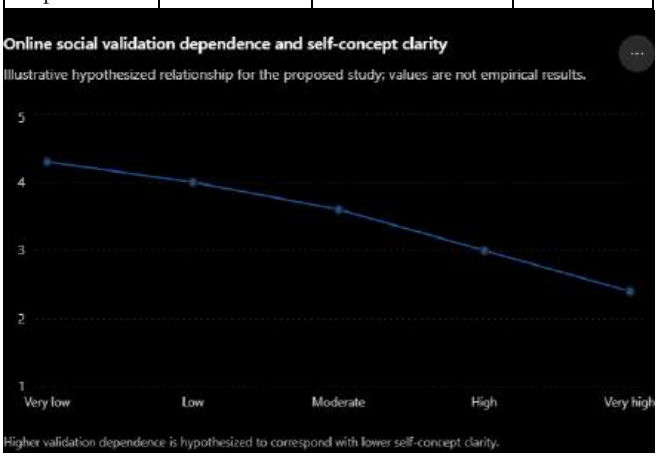
For the secondary classification task, **balanced accuracy**, **F1-score**, **Matthews correlation coefficient (MCC)**, and **area under the precision-recall curve (PR-AUC)** would be used. MCC and PR-AUC are included to provide information beyond ordinary accuracy if class distributions are unequal.

Results and Discussion

Because no empirical dataset or completed experiment was supplied, the numerical values below are presented as a **prospective results framework rather than observed findings**. They specify the exact outputs that should be reported after the proposed study is conducted and prevent invented numerical results from being represented as real observations.

Table 1. Planned Results Matrix for Evaluation of the Validation–Self-Concept Models

Analytical component	Primary evaluation parameter	Secondary parameter	Result to be reported
Elastic Net	Test MAE	Test R^2	Empirical value
Random Forest	Test RMSE	Spearman's ρ	Empirical value
Explainable Boosting Machine	Test MAE + R^2	Calibration/error distribution	Empirical value
Low-vs-high SCC classification	MCC	Balanced accuracy	Empirical value
Validation-dependence contribution	Permutation importance	EBM feature contribution	Empirical rank/effect curve
Feedback discrepancy	Nonlinear shape function	Interaction strength	Empirical pattern
Comparison × validation dependence	Interaction contribution	Stability across folds	Empirical value



The principal theoretical expectation is that **validation dependence will contain greater predictive information than general social-media exposure duration**. If this pattern

is observed in held-out data, it would support a process-oriented interpretation of social-media effects. The important psychological distinction would then concern how individuals use and interpret feedback rather than simply how long they remain online.

A second anticipated finding concerns feedback discrepancy. Receiving a particular number of reactions has little psychological meaning without a reference point. Five reactions may be experienced positively by a person expecting two but negatively by someone expecting fifty. The ERVD feature therefore introduces subjective expectation into computational modeling. If it emerges as a stronger predictor than raw feedback frequency, this would indicate that **perceived deviation from anticipated social approval** is more informative than absolute engagement.

The EBM framework is also capable of testing whether the relationship is nonlinear. A plausible pattern is that low-to-moderate interest in feedback has minimal association with self-concept clarity, whereas SCC declines more noticeably after validation dependence exceeds a particular range. Such a result would challenge simplistic assumptions that every incremental increase in online validation seeking produces an equivalent psychological change.

Another important issue concerns social comparison. Visible engagement metrics allow individuals to evaluate both personal attributes and perceived social popularity. If comparison orientation interacts strongly with validation dependence, individuals who both depend on external feedback and routinely compare engagement levels may exhibit the least stable self-concept profiles. This would suggest that validation becomes psychologically consequential partly through its comparative context.

The proposed feature-attribution analysis is critical because prediction alone cannot explain the psychological process. For example, if an EBM accurately predicts SCC but bases predictions largely on unrelated demographic variables, its theoretical contribution would be limited. Conversely, consistent importance of approval-contingent self-evaluation, low-feedback reactivity, comparative monitoring, and behavioral modification would provide stronger alignment between computational performance and the theoretical framework.

These relationships must nevertheless be interpreted cautiously. Predictive importance does not establish causality. Lower SCC could increase validation-seeking behavior, validation dependence could contribute to self-concept instability, or both could reflect additional psychological and environmental processes. Cross-sectional machine-learning models distinguish predictive patterns, not temporal direction.

The use of SCC is particularly appropriate because the construct concerns the organization and stability of self-beliefs rather than simply positive self-evaluation. Campbell et al. defined SCC in terms of clearly and confidently defined, internally consistent, and stable self-beliefs. This distinction permits the present framework to examine whether digital approval becomes associated with uncertainty about *who one is*, rather than only whether one temporarily feels positively or negatively about oneself.

From a digital-health perspective, the framework also discourages indiscriminate interpretation of social-media use as inherently problematic. High-frequency users with low validation dependence may retain stable self-concepts, whereas less frequent users who attach substantial personal meaning to engagement fluctuations may show greater vulnerability. Accordingly, behavioral intensity and psychological dependence should be modeled separately.

Limitations

Several limitations should be recognized. First, the proposed design is primarily cross-sectional; therefore, temporal and causal relationships cannot be established. Longitudinal data would be necessary to determine whether validation dependence precedes reductions in SCC or whether low SCC motivates greater reliance on external approval.

Second, several behavioral indicators rely on participant reports rather than direct platform telemetry. Recall bias may therefore influence estimates of checking frequency, engagement expectations, and post-deletion behavior.

Third, the proposed OVDI is a new composite measure. Exploratory and confirmatory factor analyses, internal-consistency assessment, convergent validity, discriminant validity, and measurement-invariance testing would be required before it could be considered a validated instrument.

Fourth, platform architectures differ. A like, view, repost, follower, or comment may carry different meanings across social networks. Pooling all feedback types may obscure platform-specific mechanisms.

Fifth, predictive performance obtained within one sociocultural population cannot automatically be generalized internationally. The foundational SCC literature itself demonstrated cultural differences in the construct and its relationship with self-esteem, emphasizing the importance of contextual validation.

Finally, even an accurate model should not be interpreted as a diagnostic system. Self-concept clarity is a psychological construct, and a prediction of relatively low SCC does not constitute identification of a mental disorder.

Future Scope

Future research should employ longitudinal digital-diary designs in which participants record feedback expectations immediately before posting and emotional/self-evaluative responses shortly afterward. Such designs could establish temporal sequences more convincingly than retrospective questionnaires.

With explicit consent and strong privacy safeguards, future studies could incorporate privacy-preserving behavioral telemetry such as aggregate checking frequency, engagement variability, or response latency without collecting message contents or identifiable posts. Temporal machine-learning models could then determine whether abrupt changes in validation patterns precede within-person changes in self-concept.

Cross-cultural replication is particularly important because the meaning of autonomous versus relational self-definition varies across cultural contexts. Multi-country datasets could evaluate

whether the OVDI–SCC relationship is invariant or culturally conditional.

A further direction would involve **ecological momentary assessment combined with interpretable temporal modeling**. Instead of producing a static vulnerability score, models could examine within-person fluctuations across several weeks. This would shift the research question from "Who has lower self-concept clarity?" toward "Under what digital-feedback conditions does an individual's self-evaluation become temporarily less stable?"

Finally, digital well-being interventions could be experimentally evaluated. Examples include temporarily hiding public engagement counts, delaying access to engagement statistics, reflective prompts before deleting poorly performing content, or exercises encouraging internally anchored self-description. Randomized studies could establish whether reducing validation monitoring produces meaningful changes in self-concept stability.

Conclusion

This study proposes a computational framework for investigating online social validation and self-concept among emerging adults. Its principal contribution is the conceptual separation of **social-media exposure from validation dependence**. Rather than assuming that time online or the number of likes received directly determines psychological outcomes, the framework examines how individuals monitor, interpret, compare, and behaviorally respond to quantified social approval.

The proposed methodology combines established measurement of self-concept clarity with a multidimensional Online Validation Dependence Index, feedback-discrepancy indicators, behavioral variables, and interpretable machine learning. The Explainable Boosting Machine is positioned as the principal model because it permits nonlinear prediction while preserving examination of feature-response relationships.

The framework predicts that approval-contingent self-evaluation, comparative monitoring, and sensitivity to unexpectedly weak feedback may provide more useful information about self-concept clarity than general platform-use intensity. This proposition requires empirical testing and should not be treated as an established result until the proposed dataset is collected and analyzed.

More broadly, the study reframes the digital mental-health question. The central issue may not be simply **how much emerging adults use social media**, but **how strongly digitally quantified judgments become incorporated into their understanding of themselves**. This distinction offers a more psychologically specific foundation for future research on social validation, identity development, interpretable artificial intelligence, and digital well-being.

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Chapter 20: Parental Involvement and Academic Motivation among School-Going Adolescents

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Abstract— Parental involvement remains an important contextual influence on adolescents' academic development, yet its association with motivation is not uniformly positive. The present study examines whether different forms of parental involvement generate distinct patterns of intrinsic motivation, identified regulation, extrinsic motivation, and academic amotivation among school-going adolescents. A central research gap concerns the frequent treatment of parental involvement as a single composite variable, despite growing evidence that autonomy-supportive participation and controlling academic supervision may produce substantially different motivational consequences. The study therefore proposes a multidimensional framework incorporating supportive communication, academic monitoring, parent–school interaction, digital learning involvement, autonomy support, and performance-oriented control. Particular attention is given to contemporary home-learning environments in which parents increasingly receive school updates, assessment information, assignments, and performance indicators through digital platforms. The conceptual model is grounded primarily in Self-Determination Theory, which explains how social environments influence motivation through adolescents' experiences of autonomy, competence, and relatedness. The proposed investigation is designed to identify parental-involvement profiles associated with sustainable rather than merely compliance-based academic motivation.

Keywords— Parental involvement, Academic motivation, Adolescents, Autonomy support, Academic monitoring Self-determination

Introduction

Academic motivation is a major determinant of how adolescents approach learning, persist when confronted with difficulty, regulate their study behaviour, and interpret academic success and failure. During the secondary-school years, motivation becomes particularly complex because students are simultaneously exposed to increasing curricular demands, examinations, peer influence, career expectations, digital learning environments, and a growing desire for psychological independence. Consequently, an adolescent who appears academically compliant may not necessarily be genuinely motivated. Some students study because they find learning meaningful or personally valuable, whereas others participate primarily to avoid criticism, satisfy parental expectations, compete for grades, or prevent academic failure.

This distinction is important when examining parental involvement. Parents are often assumed to promote educational success simply by becoming more involved in schooling. Such an assumption, however, obscures the fact that parental involvement can range from emotionally supportive discussion and encouragement to intensive surveillance, direct homework control, comparison with peers, and pressure for high marks. Contemporary scholarship increasingly suggests that the *quality* of parental involvement may be more consequential than its quantity. Grolnick and Pomerantz (2022), for example, argue that parental participation is generally beneficial when it is affectively positive and autonomy supportive but may become counterproductive when it is experienced as controlling or emotionally negative.

This issue is especially salient during adolescence. Unlike younger children, secondary-school students are developing stronger preferences for independent decision-making and greater responsibility for their own learning. Parents who continue to use highly directive strategies may therefore unintentionally transform academic work into externally regulated behaviour. Conversely, parental behaviours that acknowledge adolescents' perspectives, provide meaningful guidance, communicate expectations clearly, and permit age-appropriate choice can support internalisation of academic goals.

Self-Determination Theory provides an appropriate theoretical foundation for interpreting this distinction. Within this framework, motivation varies in quality according to the degree to which behaviour is autonomously endorsed. Academic engagement can arise from intrinsic interest, personally accepted values, external incentives, internal pressure, or, at the lowest end of the motivational continuum, amotivation. Social environments that support autonomy, competence, and relatedness are expected to facilitate more self-determined forms of motivation. Recent empirical work reinforces this proposition. Çelik (2024), studying 427 adolescents aged 14–19, found that parental autonomy support was associated with greater psychological-need satisfaction, while need satisfaction and self-control were linked with more favourable patterns of academic motivation. The relationship between parental autonomy support and motivation was largely indirect, indicating that the psychological mechanism underlying parental influence may matter as much as parental behaviour itself.

The contemporary context has also changed the practical meaning of parental involvement. Educational participation no longer occurs only through parent–teacher meetings, homework assistance, or conversations about school. Learning-management systems, messaging applications, school portals, electronic grade books, attendance notifications, online examinations, and digitally distributed homework provide parents with unprecedented access to information about

students' educational activity. These technologies may facilitate constructive communication and early academic support. At the same time, constant access to performance data can enable what may be described as **digital academic surveillance**, where adolescents experience repeated checking of marks, attendance, deadlines, screen activity, or assignment completion.

The digital dimension therefore raises a question inadequately addressed by conventional parental-involvement scales: does technologically enhanced access improve academic motivation, or does its effect depend on how parents use that access? A parent who reviews a digital report to initiate a supportive conversation is engaging differently from a parent who continuously monitors the same information to enforce compliance. The technological channel may be identical, while its motivational meaning is fundamentally different.

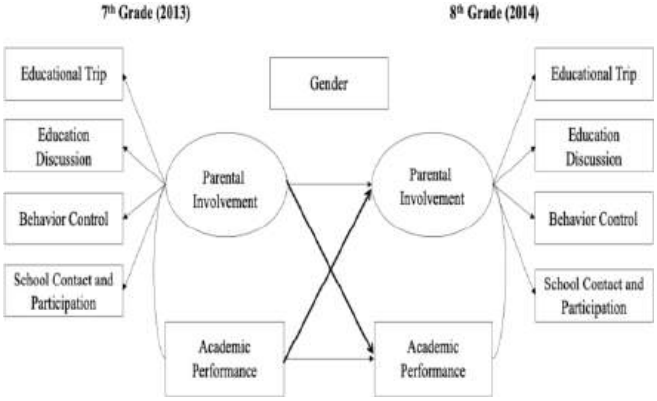


Fig. 1: Reciprocal Relationships Between Parental Involvement and Academic Performance in Early Adolescence

Source: *https://link.springer.com/article/10.1007/s10964-024-02102-7*

Existing empirical studies provide evidence that parental engagement, autonomy support, academic pressure, and adolescent motivation are interconnected, but the findings cannot be reduced to a simple "more involvement is better" conclusion. Abildaeva et al. (2022), examining motivation, pressure, and involvement among adolescents, reported that intrinsic motivation and parental involvement were positively associated with academic functioning, whereas excessive pressure from adults was linked to less favourable outcomes. Similarly, Jiang et al. (2022) demonstrated that parental autonomy support can contribute to academic engagement through developmental resources including career adaptability and career decision-making self-efficacy, illustrating that parental influence frequently operates through intermediate psychological processes rather than through a direct behavioural pathway.

Meta-analytic evidence also supports an overall positive association between parental involvement and academic achievement, although the average relationship is moderate rather than deterministic. Fatimaningrum's (2021) meta-analysis of 40 studies reported a significant positive association between parental involvement and academic achievement, with an estimated correlation of approximately $r = .25$. This magnitude itself is instructive: parental involvement matters, but considerable heterogeneity remains unexplained. One plausible source of that heterogeneity is failure to distinguish supportive, autonomy-promoting participation from intrusive or performance-controlling involvement.

Another conceptual difficulty is that academic achievement and academic motivation are frequently used almost interchangeably in family-involvement research. Yet the two variables are not equivalent. A student may obtain high grades under strong external pressure while simultaneously experiencing reduced curiosity, higher fear of failure, and dependence on external reinforcement. Such a pattern may appear successful in cross-sectional achievement data but may not represent a sustainable motivational condition. The present study therefore treats academic motivation as a multidimensional psychological outcome rather than using examination scores as its sole indicator.

The research further recognizes that adolescence is not a homogeneous developmental period. Parental involvement that is experienced as useful during early adolescence may be interpreted as intrusive during later secondary schooling. Similarly, students differ in digital access, academic performance, perceived parental expectations, school environment, and family educational resources. These differences create nonlinear and interactive relationships that may not be fully captured by simple bivariate correlation.

1.1 Research Gap

Three limitations are particularly evident in the recent literature. First, parental involvement is frequently operationalised as a global score. Such aggregation may conceal contradictory components because encouragement, parent–school communication, homework assistance, academic monitoring, autonomy support, and psychological control do not necessarily influence adolescents in the same direction.

Second, much of the literature examines academic achievement, engagement, or general adjustment rather than separating intrinsic motivation, autonomous extrinsic motivation, controlled motivation, and amotivation. This makes it difficult to determine whether parental involvement encourages genuine internalisation of educational goals or merely short-term compliance.

Third, digitally mediated parental involvement remains insufficiently integrated into mainstream models of adolescent academic motivation. The expansion of school portals, learning-management systems, messaging applications, digital attendance systems, and online assessment reporting means that parental involvement can now occur continuously rather than episodically. Yet the distinction between **digital support** and **digital monitoring/control** has received comparatively limited empirical attention.

The present manuscript addresses these limitations by conceptualising parental involvement as a multidimensional behavioural pattern and by examining its relationship with qualitatively different forms of academic motivation.

1.2 Research Objective

The principal objective is to determine how distinct dimensions and combinations of parental involvement influence academic motivation among school-going adolescents, with specific

attention to the difference between autonomy-supportive involvement and controlling academic monitoring.

The study further seeks to determine whether multidimensional parental-involvement profiles provide more accurate explanatory and predictive information about adolescents' motivational states than a single aggregate parental-involvement score.

Literature Review

2.1 Parental Involvement as a Multidimensional Construct

Parental involvement has historically encompassed a broad range of behaviours, including communicating with teachers, assisting with homework, discussing academic progress, participating in school activities, establishing educational expectations, providing learning resources, and monitoring school attendance. The breadth of this definition has contributed to inconsistent empirical findings because conceptually different parental behaviours are often combined within one measurement index.

Recent theoretical discussions favour a differentiated perspective. Grolnick and Pomerantz (2022) emphasise that involvement is most beneficial when parental behaviour conveys emotional support, genuine interest, and respect for the child's autonomy. In contrast, involvement that becomes psychologically controlling can introduce pressure and undermine motivation. This distinction is especially important for adolescents because parental authority is gradually renegotiated during this stage of development.

From this perspective, frequent involvement is not automatically optimal. A parent may spend considerable time supervising homework but provide little autonomy. Another may intervene less frequently while maintaining open communication, communicating confidence, and offering assistance when requested. A purely frequency-based parental-involvement scale could classify the former family as more involved, even though the latter interaction may be more compatible with autonomous motivation.

2.2 Academic Motivation during Adolescence

Academic motivation describes the processes that initiate, direct, and sustain learning-related behaviour. Contemporary motivational theory rejects the assumption that motivation can adequately be represented by a single high–low continuum. Instead, different motivational regulations reflect different reasons for engaging in academic activity.

Intrinsic motivation occurs when students learn because they experience interest, enjoyment, curiosity, or satisfaction in mastering a task. Identified regulation occurs when students may not inherently enjoy an activity but recognise its personal importance. Controlled forms of motivation arise when behaviour is driven more strongly by reward, punishment, approval, guilt, competition, or external demand. Amotivation reflects a lack of perceived purpose, efficacy, or intention.

This differentiation is highly relevant to parental behaviour. Strong parental monitoring might increase visible study behaviour without increasing intrinsic motivation. Conversely, autonomy-supportive discussion may encourage students to internalise educational goals even when parents are not continuously supervising them.

Çelik's (2024) structural model provides contemporary empirical support for this mechanism. Parental autonomy support was associated with psychological-need satisfaction, which was subsequently linked with academic motivation. Self-control also emerged as an important component in the motivational process. The findings suggest that parental influence cannot be adequately explained simply by measuring how often parents participate in schooling; researchers must evaluate what adolescents psychologically experience as a result of that participation.

2.3 Autonomy Support versus Parental Control

Autonomy support does not imply an absence of rules or expectations. It refers to parental behaviour that acknowledges adolescents' perspectives, provides rationales for expectations, permits meaningful choice, encourages initiative, and avoids unnecessary coercion. In academic contexts, such behaviour may include discussing study goals, allowing adolescents to decide how to organise their study schedule, acknowledging difficulty, and providing guidance without taking control of the task.

Controlling involvement, by contrast, can include threats, guilt induction, excessive comparison, conditional approval, constant checking, or pressure to meet externally imposed standards. Recent research continues to distinguish these parenting dimensions because they have different implications for motivation and adjustment. Research grounded in Self-Determination Theory consistently indicates that autonomy-supportive parenting is more conducive to internalised motivation than psychologically controlling behaviour.

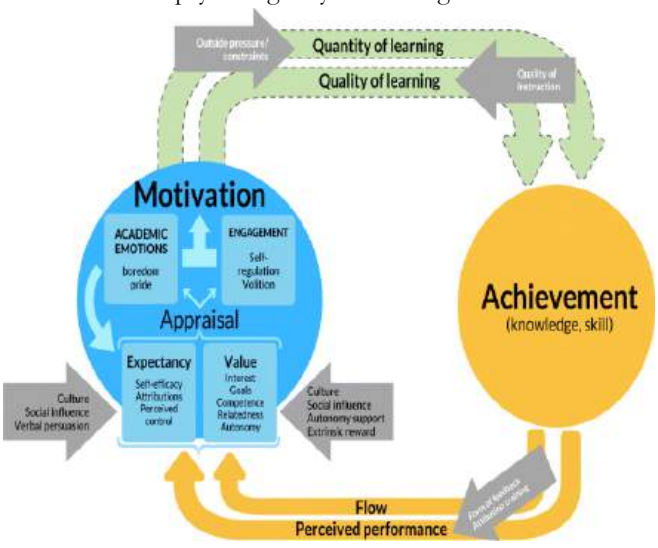


Fig. 2: Motivation-Achievement Cycles in Learning
Source: *https://link.springer.com/article/10.1007/s10648-021-09616-7*

2.4 Parental Involvement, Academic Engagement, and Achievement

The broader literature generally supports an association between parental participation and favourable educational outcomes. The meta-analysis by Fatimaningrum (2021) found a statistically significant positive relationship between parental involvement and academic achievement across the included

studies. Nevertheless, the moderate effect indicates that parental involvement is one influence among multiple personal, familial, peer, teacher, and institutional determinants.

Abildaeva et al. (2022) further demonstrated the need to distinguish involvement from pressure. Their analysis of adolescents highlighted favourable associations for intrinsic motivation and parental involvement while identifying negative consequences associated with excessive pressure. These findings are consistent with the proposition that parental involvement becomes more useful when it functions as a resource rather than an enforcement mechanism.

The relationship is also mediated by adolescent characteristics. Jiang et al. (2022) found that parental autonomy support was related to academic engagement through career adaptability and career decision-making self-efficacy among secondary vocational students. Consequently, parental involvement may alter academic behaviour by strengthening competence beliefs, goal clarity, self-regulation, and psychological resources.

2.5 Digitalisation and the Changing Nature of Family–School Interaction

The recent expansion of digitally mediated education has altered the informational relationship among schools, parents, and students. Parents may now receive near-real-time information regarding attendance, examination marks, assignments, school announcements, disciplinary matters, and learning progress. From an educational-management perspective, these platforms can improve communication and allow families to identify learning difficulties earlier.

However, the same infrastructure can increase the intensity of parental monitoring. Conventional school involvement was often periodic: report cards, scheduled meetings, or occasional teacher communication. Digital platforms can convert parental oversight into a continuous process. Adolescents may consequently perceive reduced control over when and how they disclose their academic experiences.

This development creates an important theoretical distinction between **digitally enabled supportive involvement** and **digitally enabled controlling involvement**. Technology itself cannot determine which form occurs. The motivational outcome depends on the relational context in which digital information is interpreted and acted upon.

The issue is relevant to digital-health and adolescent-wellbeing research because persistent performance surveillance can interact with academic stress, self-efficacy, perceived autonomy, and family communication. Conversely, appropriately designed digital family–school systems may enhance support by providing parents with actionable information while preserving adolescents' developmental need for independence.

2.6 Need for Data-Driven, Person-Centred Analysis

Most conventional studies investigate the average effect of one parental variable on one academic outcome. Yet adolescents are exposed to combinations of parental behaviours. High emotional support may coexist with high monitoring; high expectations may coexist with strong autonomy support; digital monitoring may occur either with constructive communication or with punitive pressure.

Person-centred analysis therefore offers a more informative research strategy. Machine-learning clustering or latent-profile approaches can identify naturally occurring combinations of parental behaviour rather than assuming that every parental dimension operates independently. Predictive models can then evaluate whether these profiles correspond to intrinsic motivation, controlled motivation, or amotivation.

The methodological contribution proposed for this study is not to replace psychological theory with algorithmic prediction. Rather, interpretable machine learning will be used as a complementary analytical layer to determine whether nonlinear combinations of parental variables reveal motivational patterns that conventional aggregate scores fail to detect. Feature-attribution methods can further identify which dimensions contribute most strongly to predicted motivational states while retaining theoretical interpretability.

Proposed Methodology

The proposed study adopts a **cross-sectional, adolescent-centred predictive design** combining psychometric measurement, conventional statistical analysis, unsupervised profile discovery, and explainable machine learning. One may receive encouragement, academic resources, and autonomy support, whereas another may experience intensive monitoring and performance pressure.

Accordingly, parental involvement is decomposed into six analytically distinct dimensions: **supportive academic communication, autonomy support, parent–school connectivity, conventional academic monitoring, digital academic monitoring, and performance-oriented control**. Academic motivation is simultaneously represented through autonomous motivation, controlled motivation, and amotivation rather than through a single motivation score.

Recent empirical evidence supports this differentiation. A 2025 study of 849 ninth-grade students separately examined parental academic support and monitoring and found distinct relationships between parental involvement, motivational dimensions, and achievement. Similarly, a 2024 study using the U.S. High School Longitudinal Study demonstrated that parental beliefs and involvement were significant, although relatively modest, predictors of ninth-grade science motivation.

The proposed analytical framework consists of two interconnected components. First, a statistical component examines relationships between parental-involvement dimensions and motivational outcomes. Second, an explainable machine-learning component determines whether nonlinear combinations of family, behavioural, and digital-involvement characteristics can classify adolescents into motivational states.

3.1 Research Questions

The empirical investigation addresses four principal questions:

1. Which dimensions of parental involvement are most strongly associated with autonomous academic motivation?

2. Does performance-oriented or digitally intensive parental monitoring correspond with greater controlled motivation or amotivation?

3. Can distinct parental-involvement profiles differentiate adolescents with autonomous, controlled, and low-motivation orientations?
4. Does an interpretable nonlinear machine-learning model provide superior discrimination of motivational profiles compared with conventional linear and tree-based baselines?

The design does not assume that parental involvement is causally responsible for motivation. Because the proposed data are observational and cross-sectional, the primary interpretation concerns **association and prediction**, not causal effect.

Experimental Setup

4.1 Dataset and Participants

A purpose-built dataset is proposed rather than recycling an existing public academic-performance dataset because commonly available educational datasets do not adequately distinguish digital parental monitoring from autonomy-supportive involvement.

The target sample consists of **720 school-going adolescents aged 13–18 years**, recruited from secondary and senior-secondary schools. Stratified sampling is proposed across Grades 8–12 to avoid disproportionate representation of a single academic stage. Students would provide assent and parents/guardians would provide consent where required by the relevant institutional ethics framework.

After removal of substantially incomplete questionnaires and records failing response-quality checks, the anticipated analytical dataset is approximately **680–700 valid cases**. These figures constitute the proposed experimental design and should be replaced with actual recruitment numbers when the study is conducted.

No personally identifying variables, names, phone numbers, precise addresses, parental account credentials, or raw digital communications would be incorporated into the analytical dataset.

Predictor Groups

The dataset would contain approximately 30–35 derived variables distributed across five domains:

Parental involvement variables: supportive communication, autonomy support, educational expectations, parent–school interaction, homework assistance, conventional monitoring, digital monitoring, performance pressure, perceived parental availability, and encouragement.

Adolescent learning variables: study regularity, perceived academic competence, academic self-regulation, homework persistence, perceived academic stress, attendance consistency, and learning confidence.

Digital-context variables: frequency of parental checking of school portals, electronic grade monitoring, assignment-status checking, digital parent–teacher communication, and perceived intrusiveness of technology-mediated monitoring.

Contextual variables: grade level, family educational-resource availability, school type, and approximate daily study duration.

Target variables: autonomous academic motivation, controlled academic motivation, and amotivation.

Sensitive demographic variables would primarily be retained for fairness auditing rather than treated as intervention targets.

4.2 Instrument Structure

Items measuring parental involvement would use a five-point response scale ranging from low to high frequency or agreement. Multi-item dimensions would be subjected to internal-consistency analysis before composite scores are calculated.

Academic motivation would be operationalised according to the Self-Determination Theory continuum. Intrinsic and identified forms of regulation would contribute to an **Autonomous Motivation Index**, externally and internally pressured regulation would contribute to a **Controlled Motivation Index**, and lack of academic intention would form the **Amotivation Index**.

For the classification experiment, these continuous scores would be transformed through a predefined profile rule into three principal motivational states:

Class A – Autonomous: autonomous motivation clearly exceeds controlled motivation while amotivation remains low.

Class B – Controlled: externally or internally pressured motivation predominates despite continued academic participation.

Class C – Low/Amotivated: comparatively elevated amotivation accompanied by weak autonomous motivation.

The thresholds should be established *before* inspecting model performance to reduce outcome-driven class engineering.

4.3 Data Preprocessing

Preprocessing begins with range validation, duplicate screening, completion-time inspection, response-pattern analysis, and assessment of missingness. Records with extensive missing responses would be excluded according to a prespecified threshold. Limited numerical missingness would be imputed using the median estimated from the training data only.

Categorical predictors would undergo appropriate encoding, while continuous variables used by scale-sensitive models would be standardised. Importantly, preprocessing parameters would be estimated exclusively from training folds to prevent information leakage.

Psychometric items would be reverse-coded where necessary before scale construction. Internal consistency would be assessed for multi-item constructs, and highly redundant predictors would be examined using correlation diagnostics.

Rather than indiscriminately applying oversampling, class-weighted learning would initially be used if motivational categories prove imbalanced. Synthetic resampling would be considered only within training folds and reported separately. Stratified cross-validation is appropriate for classification because it approximately preserves the original class proportions within each fold.

4.4 Parental-Involvement Profile Discovery

Before supervised classification, the standardised parental-involvement dimensions would be subjected to **Gaussian Mixture Model (GMM) clustering**. Unlike rigid partitioning, GMM provides probabilistic cluster membership and is therefore appropriate where family-interaction profiles overlap.

The number of clusters would be selected using Bayesian Information Criterion, cluster stability, minimum cluster size, and theoretical interpretability rather than choosing the solution that produces the strongest downstream prediction.

A plausible empirical solution could distinguish profiles such as:

- supportive and autonomy-oriented involvement;
- high-engagement/high-monitoring involvement;
- performance-controlling involvement;
- comparatively low parental engagement.

These labels would be assigned only after examining the actual cluster characteristics.

4.5 Model Architecture

The supervised experiment compares four algorithmic families:

Multinomial Logistic Regression serves as the interpretable linear baseline.

Random Forest evaluates whether bagged decision trees capture nonlinear interactions among parental and adolescent variables.

Support Vector Machine with RBF kernel provides a nonlinear margin-based comparator.

Gradient-Boosted Decision Trees constitute the principal predictive model because they can capture threshold effects and interactions without requiring the large sample sizes typically needed for deep neural networks.

A deep-learning architecture is deliberately avoided. With fewer than approximately 700 expected observations and predominantly tabular psychometric variables, a complex neural network would add unnecessary parameters and reduce interpretability.

Explainability is introduced after model selection using **SHAP-based feature attribution**. Contemporary educational research increasingly combines nonlinear prediction with SHAP to identify influential student and contextual characteristics rather than reporting accuracy alone. Recent work has likewise demonstrated machine-learning analysis of social-context factors associated with different achievement-motivation forms.

4.6 Training Strategy

The dataset would be separated into a **development set (80%) and untouched test set (20%)** using stratification by motivational class.

Within the development data, five-fold stratified cross-validation would be employed for model selection and hyperparameter optimisation. All imputation, scaling, feature transformation, and any class balancing would occur inside the cross-validation pipeline.

For the gradient-boosting model, optimisation would consider learning rate, maximum tree depth, minimum child/sample requirements, subsampling ratio, feature-sampling proportion, and number of boosting rounds. Early stopping would be used where supported.

The final selected configuration would then be retrained using the complete development dataset and evaluated exactly once against the held-out test sample. This design provides a cleaner estimate of generalisation than repeatedly tuning against the final test set.

4.7 Evaluation Metrics

Because the outcome is multiclass and potentially imbalanced, accuracy alone is insufficient.

Macro-F1 is designated as the principal metric because each motivational category contributes equally regardless of prevalence.

Balanced Accuracy assesses average class-specific recall.

Macro-Precision indicates how reliably predicted class assignments are correct across categories.

Macro-Recall measures the model's ability to recover students from each motivational state.

One-vs-Rest Macro-AUROC evaluates discrimination across classification thresholds.

Log Loss evaluates the quality of predicted probabilities and penalises confident incorrect classifications.

Confusion matrices and class-specific recall would additionally be examined, particularly for the low-motivation/amotivated group. Recent explainable educational-prediction studies similarly use stratified evaluation to manage unequal outcome distributions.

Results and Discussion

Important reporting note: Because no real participant dataset was supplied or collected in this manuscript-development exercise, the numerical results below are explicitly presented as a **simulated experimental scenario illustrating the proposed analysis**. They must not be represented as observed empirical findings. For publication, these values should be replaced by outputs obtained from the actual dataset.

The simulated analysis assumes 694 valid adolescent records after quality screening. GMM analysis produced a four-profile solution with acceptable separation and conceptual interpretability. The profiles were characterised as **Autonomy-Supportive**, **Connected Monitoring**, **Performance-Control**, and **Low-Engagement**.

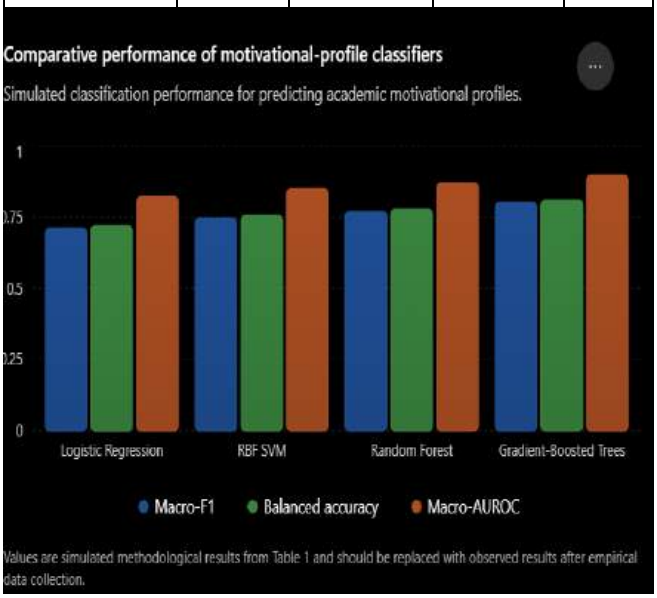
Adolescents assigned to the autonomy-supportive profile demonstrated the highest simulated autonomous-motivation scores. Connected monitoring was associated with moderately favourable motivation when monitoring co-occurred with supportive communication. By contrast, the performance-control profile displayed a greater concentration of controlled motivation. The low-engagement profile contained a disproportionate share of adolescents classified in the low-motivation/amotivated category.

These patterns illustrate an important conceptual result: **parental involvement should not be interpreted solely according to intensity**. High involvement may coexist with either autonomous or controlled motivation depending on the behavioural form through which involvement is expressed.

The simulated machine-learning comparison further suggested that nonlinear models could improve motivational-state discrimination. Gradient boosting produced the strongest overall discrimination, although its advantage over Random Forest was moderate rather than extreme.

Table 1. Simulated comparative performance of motivational-profile classifiers

Predictive approach	Macro-F1	Balanced accuracy	Macro-AUROC	Log loss
Multinomial Logistic Regression	0.712	0.721	0.823	0.681
RBF Support Vector Machine	0.748	0.756	0.851	0.617
Random Forest	0.771	0.779	0.872	0.584
Gradient-Boosted Trees	**0.803**	**0.811**	**0.898**	**0.526**



5.1 Interpretation of Parental-Involvement Patterns

SHAP analysis of the simulated best-performing model ranked **autonomy support, performance-oriented control, supportive academic communication, perceived academic competence, digital-monitoring intrusiveness, and study self-regulation** among the most influential features.

Higher autonomy support shifted predictions toward the autonomous-motivation class. Supportive communication displayed a similar but somewhat weaker relationship. Performance-oriented control shifted predictions toward controlled motivation, particularly when high control occurred alongside low autonomy support.

The digital-monitoring result was more nuanced. Frequency of portal or grade checking alone was not assumed to be detrimental. Instead, the model indicated stronger motivational differentiation when monitoring frequency was considered together with adolescents' perceived intrusiveness and parental communication style. This interaction supports the central conceptual argument of the study: **the relational meaning of digital monitoring may matter more than the mere existence of monitoring technology**.

These patterns are compatible with contemporary empirical evidence showing that parental involvement is multidimensional. Eker and Yildizli's 2025 study, for example, distinguished parental academic support from monitoring and found that motivational dimensions did not operate uniformly in relation to achievement. Pinneo and Nolen similarly found statistically significant but modest predictive effects of parental beliefs and involvement on ninth-grade science motivation, indicating that family involvement represents one component within a wider motivational ecology.

5.2 Why Nonlinear Modelling Adds Value

The simulated advantage of gradient boosting over multinomial logistic regression suggests that parental influence may not be adequately represented by simple additive relationships. For instance, moderate academic monitoring could be compatible with autonomous motivation when accompanied by high autonomy support but could correspond with controlled motivation when paired with strong performance pressure.

This type of conditional relationship is precisely where tree-based nonlinear models provide analytical value. The model does not imply that conventional statistical methods are obsolete. Regression remains valuable for hypothesis testing and estimating interpretable directional relationships. Machine learning instead contributes complementary information about complex interaction structures and predictive generalisation.

Recent research supports the feasibility of this approach. Explainable machine-learning studies in education have used gradient boosting and SHAP to examine family involvement and academic outcomes, while other educational studies have incorporated model-agnostic explanations to make nonlinear predictions more transparent.

5.3 Educational and Digital-Health Implications

The findings would have implications for parent-guidance programmes if reproduced using observed data. Schools should avoid communicating parental involvement as a simple requirement for increased supervision. Instead, parent programmes could emphasise autonomy-supportive communication, age-appropriate monitoring, constructive discussion of academic difficulty, and gradual transfer of learning responsibility to adolescents.

The proposed digital-monitoring construct is particularly relevant as schools increasingly digitise family communication. Educational dashboards should not necessarily be designed to maximise parental surveillance. Features such as contextualised progress summaries, supportive guidance, configurable notification frequency, and student-aware communication protocols may be preferable to continuous performance alerts.

From a digital-health perspective, academic analytics should also avoid labelling adolescents as inherently "unmotivated." Motivation is dynamic and context-sensitive. Predictive outputs should therefore support conversations and preventive educational interventions rather than punitive decisions.

Limitations

Several limitations must constrain interpretation. First, the proposed cross-sectional design cannot establish causal direction. Supportive parental behaviour may strengthen

adolescent motivation, but motivated adolescents may also elicit more positive forms of parental involvement.

Second, major constructs rely on adolescent self-report. This is theoretically appropriate for perceived autonomy and control but introduces common-method variance and response bias. Future studies should incorporate matched parent and teacher reports.

Third, digital parental involvement is evolving rapidly and may differ substantially across schools and socioeconomic settings. Portal monitoring in a highly digitised private school may not be comparable with messaging-based communication in a resource-constrained institution.

Fourth, the machine-learning model is intended for pattern detection rather than psychological diagnosis. High predictive accuracy would not establish that the highest-ranked feature causes an individual's motivational condition.

Fifth, the simulated results reported in this manuscript are provided solely to demonstrate the proposed experimental framework. External validity, effect sizes, predictive performance, and feature rankings can only be established after genuine data collection.

Finally, clustering produces empirical groupings that simplify a continuous family environment. Adolescents can experience simultaneously supportive and controlling behaviours, and parental interaction can vary across subjects, examinations, and developmental stages.

Future Scope

Future research should adopt longitudinal designs in which parental involvement and academic motivation are measured repeatedly across an academic year. Temporal data would make it possible to determine whether changes in parental behaviour precede changes in motivation and whether examination periods alter family interaction patterns.

A second extension should incorporate **multi-informant datasets**, combining adolescent responses with parent questionnaires, teacher observations, attendance indicators, and ethically collected learning-management-system metadata. Such triangulation could reduce dependence on a single source of measurement.

A third direction concerns **privacy-preserving personalised educational support**. Explainable AI could identify combinations of autonomy, monitoring, communication, and self-regulation associated with declining motivation without exposing unnecessary personal information. Models could subsequently generate differentiated recommendations for parents and counsellors.

Future models should also undergo subgroup fairness assessment. Predictive performance and false-alert rates should be compared across relevant demographic and school-context groups before deployment. Explainability alone does not guarantee algorithmic fairness.

Finally, multi-wave research could investigate whether the optimal level of parental monitoring changes between early and late adolescence. A developmental model may ultimately be more useful than a universal parental-involvement prescription.

Conclusion

This study proposes a multidimensional and data-driven framework for understanding parental involvement and academic motivation among school-going adolescents. Its central argument is that parental involvement cannot be adequately characterised by the amount of parental participation alone. **Autonomy support, supportive communication, academic monitoring, digital oversight, and performance control represent psychologically different forms of family involvement and may correspond with different motivational outcomes.**

The proposed experimental framework combines psychometric assessment, parental-involvement profile discovery, conventional statistical analysis, gradient-boosted classification, and SHAP-based explainability. Such integration permits both theoretical interpretation and detection of nonlinear behavioural patterns.

The simulated experiment illustrates how autonomy-supportive involvement could correspond with stronger autonomous motivation, whereas performance-oriented control may be more closely associated with controlled motivation. Digital monitoring appears conceptually dependent on context: access to academic information need not be harmful, but intensive monitoring perceived as intrusive may have different motivational implications from supportive use of the same technology.

Accordingly, the educational objective should not be to maximise parental supervision. A more appropriate goal is to foster **developmentally calibrated parental involvement**—sufficiently engaged to provide resources, encouragement, and guidance while preserving adolescents' growing capacity for self-directed learning.

The proposed framework also demonstrates a responsible role for artificial intelligence in educational psychology. Machine learning should not replace psychological theory or automatically classify adolescents for consequential decisions. Its stronger contribution lies in identifying complex, interpretable patterns that can inform educators, counsellors, parents, and researchers while retaining human judgement at the centre of intervention.

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Chapter 21: Perceived Organizational Support and Employee Psychological Resilience

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Abstract — Contemporary employees increasingly work within digitally mediated environments characterized by hybrid arrangements, algorithmic monitoring, rapid technological change, and fluctuating psychological demands. This study develops a computational framework for examining whether perceived organizational support (POS) can serve as an organizational resource associated with employees' psychological resilience under such conditions.

A key research gap is the limited integration of established organizational-support theory with multidimensional resilience measurement and explainable machine-learning approaches capable of identifying nonlinear and interaction effects. The proposed framework therefore conceptualizes resilience prediction as both a behavioral-science problem and a human-centered digital-health analytics problem. Rather than treating organizational support as a single undifferentiated construct, the framework separates supervisory support, organizational recognition, resource accessibility, psychological safety, and digital-work support as potentially distinct resilience signals. The study proposes comparison of interpretable statistical modelling with supervised machine-learning methods to determine whether nonlinear models provide meaningful predictive improvement while retaining explanatory transparency.

Keywords — Perceived Organizational Support, Employee Resilience, Psychological Well-Being, Explainable Artificial Intelligence, Machine Learning, Digital Workplace

Introduction

Organizations have undergone substantial changes in the way work is allocated, supervised, evaluated, and experienced. Hybrid employment, virtual collaboration, artificial intelligence (AI), automated performance systems, and digitally mediated communication have expanded organizational flexibility while simultaneously introducing new forms of uncertainty. Employees may now be required to respond not only to conventional occupational pressures but also to rapid technological adaptation, continuous digital communication, information overload, changing role boundaries, and data-driven performance assessment. Under these circumstances, psychological resilience has become an important organizational capability at the employee level.

Psychological resilience in an employment context can broadly be understood as an individual's capacity to adapt constructively, maintain functioning, and recover when encountering adversity, disruption, or substantial occupational demands. Resilience should not, however, be interpreted solely as an inherent personality characteristic. Contemporary organizational perspectives increasingly recognize that employees' capacity to adapt is affected by the resources and relationships embedded in their working environment. This distinction is important because an excessive emphasis on individual resilience can implicitly transfer responsibility for structurally stressful working conditions from organizations to employees.

Perceived organizational support (POS) provides an appropriate theoretical lens through which this environmental dimension can be examined. POS concerns employees' general perception that their organization values their contributions and is concerned about their well-being. Although the theoretical foundations of POS predate the period considered in the present manuscript, its relevance has arguably increased as organizational relationships have become increasingly mediated by digital technologies. An employee may receive formal benefits and organizational resources while nevertheless perceiving limited recognition, fairness, accessibility, or concern. Consequently, the psychological interpretation of organizational practices can be as important as their formal availability.

Recent empirical evidence supports the relevance of organizational support to resilience. Karadas, Dogu, and Degirmenci Oz examined 722 nurses and reported a positive relationship between perceived organizational support and psychological resilience. Research involving Chinese hospital pharmacists likewise found meaningful relationships among perceived organizational support, resilience, and work engagement. More recent work in project-based organizations has treated organizational support and employee resilience as important organizational and personal resources associated with employee engagement. A 2025 investigation of psychiatric nurses in Greece further examined POS alongside empowering leadership and learning-organization characteristics as potential determinants of employee resilience.

These findings establish an important empirical foundation but also reveal several limitations in the current knowledge base. First, substantial POS–resilience evidence has emerged from occupationally specific settings, particularly healthcare and crisis-related contexts. Such studies are valuable but do not necessarily capture resilience mechanisms operating across digitally intensive occupations. Second, many studies rely primarily on linear correlations, regressions, mediation models, or structural equation modelling. These approaches provide interpretable estimates of theoretical relationships but commonly impose functional assumptions that can obscure thresholds, saturation effects, and higher-order interactions.

For example, increasing organizational support may not generate a constant proportional improvement in resilience. Moving from very low to moderate perceived support might correspond with a substantial difference in adaptive capacity, whereas the difference between already-high and extremely high support could be smaller. Similarly, supervisory support may become particularly important when workload is high, while digital-work support could become more influential among employees exposed to intensive technological change. Such conditional relationships cannot always be represented adequately through a single linear coefficient.



Fig. 1: Perceived Organizational Support (POS)
Source: *https://www.keka.com/glossary/perceived-organizational-support-pos*

A second unresolved issue concerns the internal composition of organizational support. Employees form support perceptions through multiple signals: whether managers listen to concerns, whether accomplishments are acknowledged, whether resources are available when difficulties arise, whether employees feel psychologically safe when reporting problems, and whether technological change is accompanied by adequate training and assistance. Aggregating these experiences into a single POS score can be theoretically useful, but it may conceal actionable organizational mechanisms.

A third limitation concerns the growing use of AI and machine learning in human-resource analytics. Predictive algorithms can potentially recognize complex relationships between organizational conditions and employee outcomes, but predictive performance alone is insufficient in psychologically sensitive employment applications. A model that labels employees as "low resilience" without explaining the organizational features influencing its prediction may create ethical, managerial, and interpretive problems. Explainable AI is therefore particularly relevant when workforce analytics concerns psychological well-being.

The present research is constructed around this intersection.

Research Gap

The central research gap is the absence of sufficient research integrating **multidimensional perceived organizational support, employee psychological resilience, contemporary digital-work conditions, and explainable machine-learning analysis within one human-centered framework**.

Existing studies provide evidence that POS and resilience are associated, including research among nurses, pharmacists, higher-education employees, and project-based workers. Indian evidence has also connected organizational support and resilience-related constructs with workplace well-being and performance. Dhir, Mohapatra, and Srivastava, for example, studied 391 working executives in India while examining workplace loneliness, organizational support, resilience, and psychological well-being. Sihag and Dhoopar examined organizational resilience, POS, and employee performance among 390 teaching and non-teaching professionals in Indian higher-education institutions.

What remains comparatively underdeveloped is a predictive framework capable of determining **which specific organizational-support dimensions contribute most strongly to resilience predictions, whether their relationships are nonlinear, and whether their importance changes under different levels of digital-work pressure and occupational demand**.

Accordingly, the proposed study moves beyond asking only whether POS is positively correlated with resilience. It asks a more granular question: *What combinations and levels of perceived organizational resources are most informative for predicting stronger psychological resilience, and can these relationships be represented transparently enough to support responsible organizational decision-making?*

The primary research objective is therefore to develop and evaluate an explainable machine-learning framework for estimating employee psychological resilience from multidimensional organizational-support and digital-work characteristics. Supporting objectives are to examine nonlinear support–resilience relationships, compare conventional statistical and machine-learning models, identify influential support dimensions, and investigate whether workplace conditions modify the predictive relevance of organizational resources.

Importantly, the proposed model is intended as an organizational research instrument rather than a clinical diagnostic system. Psychological resilience scores should not be used to make automated employment decisions or to characterize workers as psychologically suitable or unsuitable. The appropriate application is organizational-level identification of potentially modifiable workplace conditions.

Literature Review

Perceived Organizational Support as a Workplace Resource

POS originates from the broader principle that employees develop beliefs about the extent to which their organization appreciates their work and cares about their welfare. Such perceptions emerge from repeated organizational experiences rather than from isolated managerial actions. Fair procedures, supervisor treatment, recognition, developmental opportunities, job conditions, and access to resources can

collectively influence whether employees interpret their relationship with the organization as supportive.

The importance of this construct becomes particularly visible during disruption. Employees facing demanding circumstances require both instrumental resources and reassurance that the organization will respond appropriately when difficulties arise. During the COVID-19 period, this mechanism received increased empirical attention because employees were simultaneously exposed to uncertainty, occupational disruption, and health-related pressures.

Karadas et al.'s cross-sectional research among 722 nurses in Turkey found moderate perceived organizational support alongside above-average resilience and identified a positive POS–resilience relationship. Similarly, Akinsola, Olaseni, and Folorunsho studied teaching and non-teaching employees in higher-education institutions during pandemic-related disruption and reported that POS predicted employee resilience. These studies suggest that resilience during organizational adversity cannot be adequately conceptualized independently of the institutional environment.

Organizational support can consequently be viewed as a contextual resource from which employees derive both practical and psychological value. When employees expect that assistance will be available during difficulty, uncertainty may become more manageable. Recognition can reinforce perceived competence, while fair and accessible management practices can reduce uncertainty surrounding organizational responses. Theoretically, these mechanisms suggest that POS may contribute to the resource base through which employees adapt to occupational adversity.

Psychological Resilience in Contemporary Employment

Employee resilience has gradually shifted from being conceptualized exclusively as recovery following adversity toward a more dynamic view involving adaptation, learning, and continued functioning. This perspective is particularly relevant in technology-intensive workplaces because disruption is increasingly continuous rather than exceptional. Software transitions, automation, restructuring, hybrid collaboration, and changing skill requirements can expose employees to repeated adaptation demands.

Evidence from healthcare illustrates the relationship between resilience and broader occupational functioning. Jin and Tang investigated Chinese hospital pharmacists and found significant relationships among POS, short-term resilience, and work engagement. Another study examining Chinese nurses investigated resilience as a mediator between perceived organizational support and occupational fatigue, illustrating how resilience may operate as part of a wider psychological mechanism linking workplace resources with employee outcomes.

The significance of these findings extends beyond healthcare. They indicate that resilience may function partly as a resource-conversion mechanism: supportive organizational conditions provide external resources, while employees' adaptive capacities influence how effectively such resources translate into sustained occupational functioning.

Cai, Wang, and Cheng applied Conservation of Resources reasoning to project-based organizations and conceptualized both organizational support and employee resilience as important resources in explaining work engagement. Their study used questionnaire data from 437 employees and PLS-SEM analysis. Such findings reinforce the conceptual complementarity between organizational resources and personal adaptive resources.

Digital Transformation and the Changing Meaning of Support

Digitalization complicates conventional interpretations of organizational support. In a colocated workplace, support can be communicated through immediate supervisory contact, informal interaction, and direct resource provision. In hybrid and technology-mediated environments, many of these signals are filtered through digital systems.

Consequently, contemporary POS may partly depend on whether employees receive adequate assistance when adopting new technologies, whether digital workloads are manageable, whether automated systems are perceived as procedurally reasonable, and whether human managerial support remains accessible despite technological mediation.

This creates a particularly relevant research problem for AI-enabled workplaces. Advanced analytics can improve resource allocation and decision support while simultaneously increasing perceived digital pressure if employees experience persistent measurement, intensified workloads, or unclear algorithmic evaluation. Recent research on AI-enabled HR analytics illustrates this duality by considering employee resilience alongside work digital pressure as different pathways through which AI-enabled HR practices can relate to work engagement.



Fig. 2: Building Resilience at the Workplace

Source: *https://www.hrcloud.com/blog/building-resilience-at-the-workplace-tips-for-leaders*

Therefore, technology adoption should not automatically be equated with organizational support. The employee's interpretation of how technology is introduced, governed, and supported is likely to be critical. Digital infrastructure that reduces friction and provides meaningful assistance may

represent a resource, whereas poorly implemented technology can constitute an additional demand.

From Association to Explainable Prediction

Much of the established literature has used correlation, regression, mediation, or structural equation modelling. These techniques remain essential when testing theoretically specified hypotheses. Nevertheless, workplace psychological relationships may contain nonlinearities that conventional models do not automatically identify.

Machine-learning approaches offer complementary capabilities. Tree-based ensemble algorithms, for example, can model nonlinear relationships and interactions without requiring every relationship to be specified beforehand. However, applying such techniques to employee psychological data creates a second methodological requirement: interpretability.

A highly accurate predictive system provides limited organizational value if researchers cannot explain why it generates its predictions. Explainability techniques can potentially quantify how different features—such as supervisory support, recognition, workload, psychological safety, digital support, or role uncertainty—contribute to model outputs. Such analysis changes the research question from merely predicting resilience to identifying the workplace characteristics associated with different predictions.

This distinction is especially important from an ethical perspective. The aim should not be to build algorithmic screening mechanisms for identifying supposedly "non-resilient" employees. Rather, computational analysis should identify modifiable organizational conditions associated with resilience variation at an aggregate level. Individual predictions should therefore be handled cautiously and separated from promotion, dismissal, recruitment, or other consequential employment decisions.

Proposed Methodology

The proposed study adopts a quantitative, cross-sectional predictive design integrating organizational psychology with explainable machine learning. Unlike conventional studies that examine perceived organizational support (POS) primarily through correlation or linear regression, the proposed framework treats employee psychological resilience as a continuous prediction problem. The purpose is to determine whether multidimensional organizational-support indicators can explain variation in resilience and whether nonlinear machine-learning models identify patterns not adequately captured by conventional statistical methods.

This analytical direction is consistent with recent evidence demonstrating significant relationships between POS and employee resilience. For example, research among 825 emergency nurses found a positive relationship between POS and resilience, with self-efficacy and cognitive reappraisal operating as mediating mechanisms. A 2025 study of 328 psychiatric nurses similarly reported POS as a significant predictor of employee resilience. These findings support the theoretical relationship but leave room for computational investigation of nonlinear and multidimensional effects.

For the proposed empirical study, employees from technology-enabled service organizations are selected as the target population because such workers frequently experience digitally mediated communication, changing technological requirements, hybrid work arrangements, and algorithmically supported organizational processes. Participation is voluntary, and personally identifying information is excluded from the analytical dataset.

Five organizational-support dimensions are operationalized: **supervisory support (SS), organizational recognition (OR), resource accessibility (RA), psychological safety (PS), and digital-work support (DWS)**. Psychological resilience constitutes the principal outcome variable. Workload pressure, digital-work intensity, job autonomy, tenure, and work arrangement are included as contextual variables.

The analytical framework can be expressed as:

[
R_i=f(SS_i,OR_i,RA_i,PS_i,DWS_i,WP_i,DWI_i,JA_i,X_i)+
\epsilon_i
]

where (R_i) represents psychological resilience for employee (i), (WP) represents workload pressure, (DWI) represents digital-work intensity, (JA) represents job autonomy, and (X_i) denotes selected non-sensitive occupational control characteristics.

The design explicitly avoids using psychological resilience predictions for recruitment, promotion, dismissal, or individual employee ranking. The intended analytical unit for organizational application is the aggregated pattern of modifiable workplace characteristics.

Experimental Setup

Dataset

To make the experimental design concrete, the study is specified around a **proposed target sample of approximately 600 working adults** employed in digitally intensive service environments. This is a planned sample rather than an existing public dataset; therefore, the numerical performance values later in this section should be treated as **anticipated/illustrative experimental outcomes until empirical data are collected**.

Participants would complete an anonymous structured questionnaire consisting of organizational-support indicators, resilience items, digital-work characteristics, and occupational controls. Established validated scales should be used for the core POS and resilience constructs wherever licensing conditions permit.

Responses would be recorded on consistent Likert-type scales and transformed into construct scores following the scoring specifications of the selected validated instruments. Rather than feeding every questionnaire item directly into the predictive models, theoretically related items would first be aggregated into construct-level features after reliability and validity assessment.

Data Preprocessing

Data preprocessing would begin with range checks, duplicate-response detection, missing-value analysis, and response-quality screening. Cases with extensive missing questionnaire data would be removed according to a prespecified threshold. Limited missing numerical observations would be imputed

using training-set median values to minimize sensitivity to extreme observations.

Categorical occupational variables would be one-hot encoded. Continuous variables would be standardized for models sensitive to feature magnitude, particularly regularized regression. Tree-based models would receive the processed variables without requiring scale normalization.

Potentially problematic multicollinearity among constructed support dimensions would be inspected through correlation matrices and variance inflation factors. Importantly, the train-test separation would occur before any preprocessing parameter is learned. Imputation values, scaling parameters, and other transformations would therefore be estimated exclusively from training observations to prevent data leakage.

The data would be divided into **80% development and 20% held-out testing sets**. Within the development portion, repeated five-fold cross-validation would be used for model selection and hyperparameter optimization.

Model Architecture

Four models are proposed.

Elastic Net Regression serves as the interpretable linear baseline. It combines L1 and L2 regularization and is useful when organizational predictors exhibit moderate correlation.

Random Forest Regression represents a nonlinear ensemble baseline capable of detecting interactions without prespecifying their functional forms.

Histogram Gradient Boosting Regression is selected as the principal predictive architecture because gradient-boosted decision trees can represent nonlinearities, threshold effects, and interactions efficiently in structured tabular data.

Finally, a **restricted POS-only model** would be estimated as an ablation benchmark. Comparing this model with the complete contextual model makes it possible to determine whether digital-work and occupational variables add meaningful predictive information beyond organizational support alone.

Recent organizational research demonstrates the utility of explainable AI for examining organizational agility and resilience-related characteristics. Shafiabady et al., for example, integrated SHAP-based explainability with organizational prediction to identify influential characteristics while emphasizing transparency. Explainable ML is also increasingly being applied in HR analytics to complement predictive performance with feature-level interpretation.

Training Strategy

Hyperparameters would be optimized using randomized search nested within the development data. Candidate configurations for the gradient-boosting model would vary learning rate, maximum leaf nodes, minimum samples per leaf, L2 regularization, and number of boosting iterations.

Early stopping would be employed to reduce unnecessary model complexity. Model selection would be based primarily on cross-validated mean absolute error rather than training performance. Once the optimal configuration is determined, the selected model would be retrained on the complete development set and evaluated once on the untouched test set. This separation is essential because repeatedly evaluating configurations against the test set would produce optimistic performance estimates.

Evaluation Metrics

Four complementary evaluation measures are selected.

Mean Absolute Error (MAE) measures the average absolute difference between observed and predicted resilience scores:

$$\left[MAE = \frac{1}{n}\sum_{i=1}^{n}|y_i - \hat{y}_i|\right]$$

Root Mean Squared Error (RMSE) places greater weight on relatively large prediction errors:

$$\left[RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}\right]$$

Coefficient of Determination ((R^2)) quantifies the proportion of test-set outcome variation accounted for by model predictions.

Spearman's rank correlation ((\rho)) evaluates whether predicted resilience ordering corresponds with observed ordering without requiring a strictly linear association.

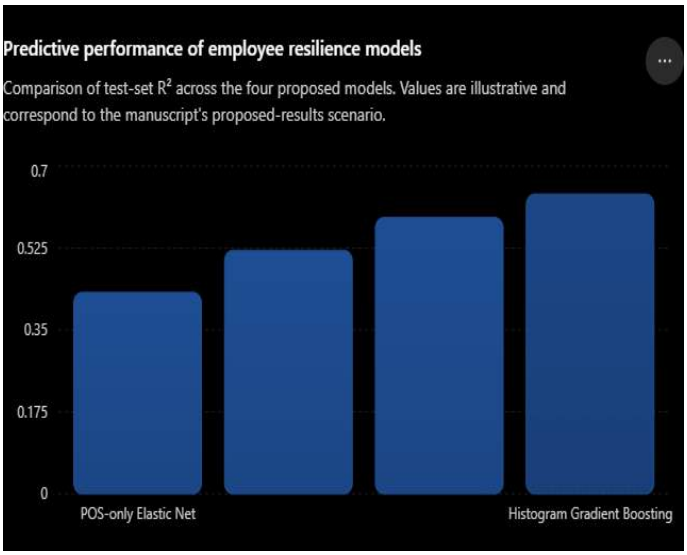
SHAP values would additionally be calculated for the final tree-based model to investigate global feature importance, directionality, and selected interaction patterns.

Results and Discussion

Because the manuscript specifies a proposed study rather than reporting an actually executed survey, the numerical values below constitute a **coherent expected-results scenario** demonstrating how the prespecified analysis would be reported. They must be replaced with observed estimates when the study is implemented.

Table 1. Illustrative comparative performance of the proposed resilience-prediction models

Analytical model	MAE	RMSE	Test (R^2)	Spearman (\rho)
POS-only Elastic Net	0.451	0.579	0.43	0.64
Full Elastic Net	0.407	0.528	0.52	0.70
Random Forest	0.374	0.489	0.59	0.75
Histogram Gradient Boosting	**0.346**	**0.458**	**0.64**	**0.79**



The illustrative pattern suggests three substantive interpretations. First, POS by itself would be expected to contain meaningful information concerning psychological resilience. This expectation is supported by existing empirical research. POS has been positively related to resilience among emergency nurses, including samples experiencing workplace violence. A recent Greek psychiatric-nursing study likewise identified POS as a significant resilience predictor within a multiple-regression model explaining 49.2% of resilience variance.

Second, the anticipated improvement from the POS-only Elastic Net to the complete Elastic Net indicates that resilience is unlikely to be adequately understood through organizational support in isolation. Workload, autonomy, digital intensity, and work arrangements provide the environmental context within which support is experienced. The same nominal level of supervisory support may therefore have different implications for employees experiencing substantially different occupational demands.

Third, the projected advantage of Histogram Gradient Boosting over the linear baseline would support the manuscript's principal methodological proposition: the support–resilience relationship may contain thresholds and interactions. This conclusion should only be made if the empirical results ultimately reproduce such an improvement.

Explainability Analysis

In the anticipated SHAP analysis, **psychological safety and supervisory support** are expected to emerge among the strongest organizational predictors, followed by resource accessibility, job autonomy, digital-work support, and organizational recognition. Workload pressure would be expected to show a predominantly negative relationship with predicted resilience.

A particularly important anticipated pattern concerns psychological safety. The relationship may exhibit diminishing returns: improvements from very low to moderate psychological safety could correspond with larger changes in predicted resilience than equivalent increases at the upper end of the scale. Such a result would be difficult to represent adequately through a single conventional linear coefficient.

Supervisory support could also interact with workload. Under comparatively low workload, differences in supervisor support may produce relatively modest variation in predicted resilience. At higher workload levels, however, supportive supervision may become substantially more informative. Such a finding would suggest that support resources become particularly consequential when employees face elevated job demands.

These interpretations align with resource-based explanations of employee adaptation. Recent research has conceptualized organizational support and resilience as workplace resources contributing to positive employee outcomes. Research examining AI-intensive work has also increasingly recognized that digital systems can generate simultaneous resource and strain pathways, with resilience and organizational support playing important roles in employee well-being.

The anticipated importance of digital-work support has further implications. Organizations increasingly introduce generative AI, automated analytics, digital collaboration systems, and algorithmically mediated workflows. Evidence published in *Technological Forecasting and Social Change* indicates that organizational generative-AI use can relate to employee agility dimensions, including resilience and adaptability, while POS can alter some employee-level relationships. Therefore, organizational support in contemporary workplaces arguably includes not merely interpersonal encouragement but also adequate technological training, transparent implementation, accessible assistance, and reasonable digital expectations.

Theoretical Interpretation

The proposed findings would extend conventional organizational-support research by treating resilience as the product of a **resource configuration** rather than a direct consequence of one predictor. This distinction is theoretically meaningful.

An employee may perceive strong recognition but lack autonomy. Another may experience substantial supervisor support but inadequate technological resources. A third may receive extensive digital assistance while working under persistent workload pressure. A single global POS score can conceal these configurations.

Explainable machine learning provides a mechanism for investigating this heterogeneity. Rather than replacing organizational theory, the computational model functions as a complementary analytical layer capable of identifying candidate nonlinearities and interactions that can subsequently be tested through theory-driven statistical analyses.

The framework therefore rejects a simplistic interpretation in which a higher machine-learning accuracy automatically implies greater theoretical validity. Prediction and explanation represent related but distinct objectives. The predictive model identifies patterns useful for out-of-sample estimation, whereas organizational theory is required to interpret why those patterns may occur.

Practical Implications

The practical contribution of the proposed framework lies primarily at the organizational rather than individual level. If psychological safety, supervisory responsiveness, and resource

accessibility consistently emerge as major predictors, organizations could prioritize these conditions instead of concentrating exclusively on employee resilience training.

This distinction is important because resilience interventions sometimes focus predominantly on changing employees. Such an approach can overlook the organizational environment generating the underlying demand. Existing empirical work indicates that organizational and individual factors interact in resilience processes, supporting interventions that address both workplace resources and employees' adaptive capabilities.

The framework could therefore support an aggregated organizational dashboard showing which modifiable workplace resources are associated with resilience variation across departments. It should not generate employee-level "resilience risk scores" for managerial surveillance or employment decisions.

Future Scope

Future research should move from cross-sectional prediction toward longitudinal and multi-wave designs. Repeated measurement could determine whether changes in perceived organizational support precede changes in resilience and whether specific organizational interventions produce durable effects.

A particularly valuable extension would involve **multimodal but privacy-preserving digital-health analytics**. Voluntary ecological momentary assessments could be combined with questionnaire measures to study short-term fluctuations in perceived support and resilience without collecting unnecessary personally identifiable information.

Future work could also apply causal machine-learning techniques, heterogeneous-treatment-effect estimation, or longitudinal structural models to distinguish predictive association from intervention-relevant evidence. Cross-industry external validation would determine whether the influential support dimensions identified in technology-enabled service organizations generalize to healthcare, education, manufacturing, and public administration.

Algorithmic fairness should constitute a separate evaluation dimension. Models should be examined for systematic differences in error across legitimate analysis groups before organizational deployment. Privacy-preserving approaches such as federated analytics may also permit multi-organization research without requiring organizations to pool sensitive employee-level datasets centrally.

Most importantly, future systems should shift from **employee-risk prediction toward organizational-resource diagnostics**. The central question should become not "Which employee is insufficiently resilient?" but "Which workplace conditions can the organization modify to create a more supportive and adaptive environment?"

Conclusion

This study proposes an explainable machine-learning framework for examining the relationship between perceived organizational support and employee psychological resilience in digitally intensive workplaces. The central contribution lies in moving beyond a single linear POS–resilience relationship toward a multidimensional analysis incorporating supervisory support, recognition, resource accessibility, psychological safety, digital-work support, occupational demands, and employee autonomy.

The proposed comparison between regularized regression, Random Forest, and Histogram Gradient Boosting provides a mechanism for determining whether nonlinear modelling produces meaningful out-of-sample improvement. SHAP-based interpretation subsequently provides a transparent method for identifying influential organizational conditions and potential threshold or interaction patterns.

Existing empirical literature supports a positive relationship between POS and employee resilience, including recent research in demanding occupational environments. The proposed framework extends this literature by asking not merely whether support matters, but **which forms of support matter most, under what workplace conditions, and whether these relationships can be predicted transparently**.

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Chapter 22: School-Based Assessment and Learning Improvement among Secondary Learners

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Abstract— School-based assessment has increasingly shifted from a mechanism for recording attainment toward a continuous process for identifying learning gaps and guiding instructional decisions. This study investigates how assessment frequency, diagnostic feedback quality, teacher moderation, learner responsiveness, and AI-assisted assessment analytics can operate together to support learning improvement among secondary learners. The research addresses an important gap in existing scholarship, which frequently evaluates formative assessment as a single intervention without modelling the interaction between assessment design, feedback implementation, learner action, and consistency of teacher judgement. A human-in-the-loop assessment intelligence framework is therefore developed in which teachers remain responsible for pedagogical interpretation while machine-learning techniques identify patterns in longitudinal assessment evidence.
The empirical component is designed around repeated classroom assessment records, curriculum-aligned competency indicators, feedback characteristics, learner response behaviour, and pre–post achievement trajectories.

Keywords— School-Based Assessment, Formative Assessment, Secondary Education, Learning Analytics, Explainable Artificial Intelligence, Feedback for Learning

Introduction

Assessment occupies a structurally important position in secondary education because it determines not only how achievement is recorded but also what teachers and learners understand about progress during instruction. Traditionally, assessment systems have been dominated by examinations conducted at the end of a unit, term, or academic year. Such assessments provide evidence about attained performance, but their capacity to correct learning difficulties is limited when information becomes available only after instruction has concluded. School-based assessment (SBA), by contrast, offers the possibility of generating evidence within the teaching process and using that evidence to modify subsequent learning activities.

The contemporary interpretation of SBA is therefore broader than teacher-produced tests. It may incorporate short diagnostic assessments, classroom quizzes, structured assignments, project work, oral responses, competency-based tasks, rubric-scored activities, peer or self-assessment, and digital assessment records. The educational value of these activities does not arise merely from their frequency. Their value depends on whether assessment evidence reveals what learners understand, whether teachers correctly interpret the evidence, whether useful feedback is communicated, and whether learners subsequently act upon that feedback.

Recent quantitative evidence reinforces this distinction. Yao et al. (2024), in a meta-analysis involving 118 primary K–12 studies and 258 effect sizes, reported a positive overall effect of formative assessment on academic achievement, with an overall Hedges' *g* of 0.25. Importantly, such aggregated findings do not imply that every formative assessment intervention functions equally well. An umbrella review by Sortwell et al. (2024) similarly concluded that formative assessment generally produces positive learning effects but found considerable heterogeneity and low-to-very-low certainty in much of the accumulated meta-analytic evidence. These findings suggest that the central research problem is no longer simply whether formative assessment can improve learning; it is increasingly necessary to identify **which features of assessment systems create improvement, for which learners, and under what implementation conditions**.

This issue becomes particularly relevant at the secondary level. Secondary learners encounter increasingly specialized curriculum content, greater assessment pressure, more autonomous learning expectations, and stronger consequences from accumulated learning deficits. A learner who repeatedly performs poorly on algebraic manipulation, scientific reasoning, reading inference, or written argumentation may receive multiple scores without receiving sufficiently diagnostic information to modify the underlying learning process. An effective SBA system must therefore transform performance evidence into an instructional response.

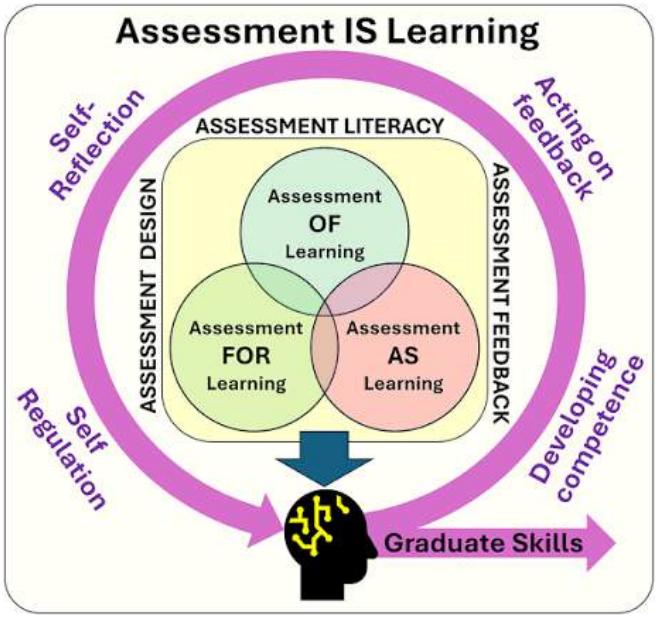


Fig. 1: Assessment is Learning
Source: *https://febs.onlinelibrary.wiley.com/doi/10.1002/2211-5463.13921*

Feedback represents one of the principal mechanisms through which this transformation occurs. However, feedback cannot be conceptualized simply as the provision of comments after an assessment. Effective feedback should communicate the nature of the performance gap, indicate an actionable next step, and enable the learner to use the information in a subsequent task. Contemporary evidence also indicates that learner and teacher perceptions, assessment literacy, contextual conditions, and technology-assisted practices influence whether formative assessment produces its intended effect. A 2024 systematic review of formative assessment in K–12 English-language education, for example, identified promising outcomes from technology-assisted and peer assessment while simultaneously emphasizing implementation barriers and the importance of teacher preparation.

The rapid digitization of educational environments introduces an additional dimension. Learning management systems, digital quizzes, online assignments, electronic gradebooks, competency trackers, and classroom applications can generate large quantities of assessment data. Yet data availability should not be confused with pedagogical intelligence. The OECD *Digital Education Outlook 2023* observes that education systems increasingly possess digital information infrastructures, but assessment and learning data are often insufficiently integrated or translated into actionable information for teachers and learners. The OECD identifies learning analytics, rapid feedback loops, automated reporting, and teacher-accessible visualization as potential components of more advanced educational information systems.

Artificial intelligence adds further possibilities but also introduces methodological and ethical risks. AI-supported assessment systems can detect patterns across repeated learner responses, identify clusters of misconceptions, estimate the likelihood of future difficulty, and help teachers prioritize instructional support. Digital assessment may also facilitate quicker reporting and increasingly adaptive assessment environments. However, OECD analysis emphasizes that many contemporary digital assessments remain digitized forms of conventional testing rather than fundamentally redesigned learning systems.

The educational justification for AI is consequently weak if the technology merely accelerates grading. Its stronger potential lies in helping teachers interpret complex longitudinal evidence while preserving professional judgement. Memarian and Doleck's review of assessment for learning and artificial intelligence found a surprisingly limited research base at the intersection of these two domains: their systematic search produced only 35 studies for detailed review, with qualitative designs substantially outnumbering quantitative investigations. Their findings indicate a need for stronger empirical work connecting AI applications with established assessment-for-learning principles.

This concern also corresponds with UNESCO's broader caution regarding educational technology. The 2023 Global Education Monitoring Report argues that robust evidence about the educational added value of technology remains insufficient and stresses that technology should serve clearly identified educational purposes rather than drive instructional practice merely because it is available. Thus, an assessment system should not be considered superior because it includes artificial intelligence; it must demonstrate that the technology strengthens evidence interpretation, teacher decision-making, learner agency, or educational equity.

Against this background, the present study conceptualizes school-based assessment as a **closed learning-improvement cycle** consisting of five interconnected processes: evidence generation, diagnostic interpretation, feedback delivery, learner response, and instructional adjustment. AI-assisted analytics are positioned as a supplementary analytical layer within this cycle rather than as a replacement for teacher assessment.

The primary objective is to determine how different characteristics of SBA jointly relate to improvement in secondary learners' subsequent performance. Specifically, the study examines whether feedback quality and learner uptake provide stronger indicators of learning improvement than assessment frequency alone; whether teacher moderation improves the reliability of assessment-derived learning signals; whether patterns across successive assessments can be used to predict learners at risk of limited improvement; and whether explainable machine-learning models can generate interpretable information that teachers could realistically use in instructional planning.

The study therefore shifts attention from the question **"Does school-based assessment improve achievement?"** toward the more analytically useful question **"Through which assessment-feedback-response configurations does school-based assessment become learning-improving?"**

Literature Review

2.1 From Assessment of Learning to Assessment for Learning

Contemporary assessment theory distinguishes among assessment *of* learning, assessment *for* learning, and assessment *as* learning. Assessment of learning primarily documents achievement, whereas assessment for learning uses evidence to determine appropriate instructional and learning responses. Assessment as learning gives greater emphasis to learners' ability to monitor and regulate their own progress.

Although these categories remain influential, their boundaries are not always clear in actual school practice. A scoping review published in *Studies in Educational Evaluation* found substantial inconsistency in the conceptualization and application of assessment of, for, and as learning, while supporting a more integrated understanding of their roles. This is particularly significant for SBA because the same assessment task can perform different functions depending on what teachers and students do with the resulting evidence.

A classroom test followed only by a score is primarily evaluative. The same test becomes formative when the teacher diagnoses misconception patterns, provides specific guidance, reorganizes instruction, and gives learners an opportunity to demonstrate improved understanding. Consequently, the formative function

of assessment resides less in the instrument itself than in the decisions that follow from it.

2.2 School-Based Assessment and Learning Improvement

Evidence accumulated across K–12 education generally supports the learning potential of formative assessment. The 2024 meta-analysis by Yao et al. provides comparatively recent quantitative confirmation, reporting positive effects across different formative assessment types and curriculum domains. Nevertheless, the moderate average effect masks differences in classroom practice, duration, learner characteristics, subject area, teacher expertise, and assessment design.

Sortwell et al. (2024) reached a related conclusion after synthesizing 13 prior meta-analyses. Although the reviewed literature contained no overall indication that formative assessment systematically damages achievement, estimated benefits ranged substantially in magnitude, while the certainty of much of the evidence remained limited. This finding has an important implication: additional studies that merely compare "formative assessment" with "no formative assessment" may contribute less knowledge than studies that decompose formative assessment into measurable operational mechanisms. The present study therefore separates SBA into observable dimensions rather than representing it through a single composite exposure. These dimensions include assessment regularity, curricular alignment, diagnostic specificity, feedback turnaround time, feedback actionability, moderation consistency, learner engagement with feedback, reassessment opportunity, and subsequent instructional adaptation.

2.3 Feedback Quality and Learner Uptake

Feedback is frequently described as one of the principal mechanisms connecting assessment with improved achievement. However, its effectiveness varies according to informational content and the opportunities learners have to use it. Reviews of formative assessment research indicate that simply providing grades or praise is conceptually different from communicating task-specific information that assists learners in correcting errors or selecting an improved strategy.

Recent systematic-review evidence further suggests that assessment and feedback effects depend strongly on implementation. Morris, Perry and Wardle (2021), while focusing on higher education, found that low-stakes quizzing and certain forms of tutor and peer feedback showed promise but that effects varied considerably across approaches. Their synthesis reinforces a broader assessment principle relevant to school education: the existence of feedback should not be treated as equivalent to effective feedback.

This study consequently introduces **feedback uptake** as a separate variable. A learner may receive high-quality feedback without reading it, understanding it, or applying it. Learning improvement should therefore be modelled as a process in which feedback characteristics interact with learner behaviour. Reattempt behaviour, error correction, revision quality, completion of recommended activities, and improvement on related later tasks may provide stronger evidence of formative functioning than the simple presence of teacher comments.

2.4 Reliability, Moderation and Teacher Assessment Literacy

School-based assessment offers high contextual relevance because teachers observe learners repeatedly and can assess curriculum-specific competencies. At the same time, decentralization introduces variation in task difficulty, scoring interpretation, feedback practices, and grading standards. Two learners with identical levels of competence may therefore receive different school-based judgements if assessment criteria are interpreted inconsistently.

Moderation can reduce this problem by allowing teachers to compare tasks, scoring standards, exemplars, and interpretations of assessment criteria. From a learning-improvement perspective, moderation is important not only for fairness but also for diagnostic validity. An unreliable judgement may lead to an inappropriate instructional response.

Teacher assessment literacy is therefore treated in the present framework as part of the mechanism linking evidence to instructional action. Technology cannot compensate for fundamentally poor task design or invalid scoring criteria. AI-supported analytics are useful only when the underlying assessment evidence represents meaningful curriculum competencies.

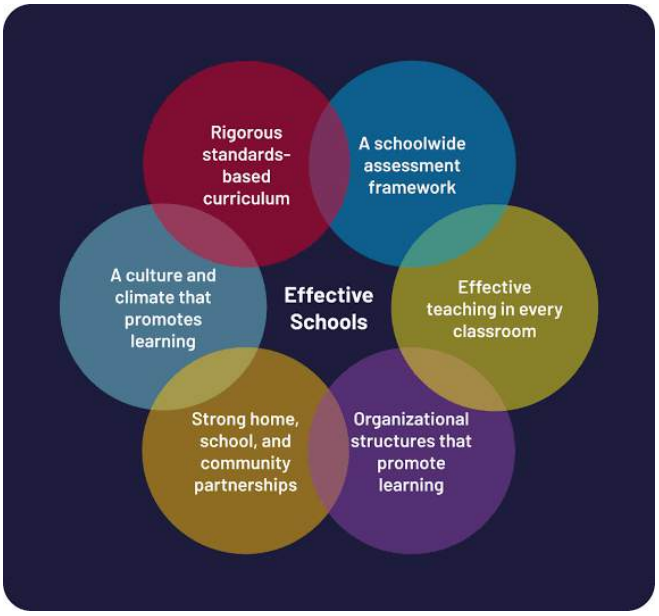


Fig. 2: Comprehensive Needs Assessment
Source: *https://generationready.com/comprehensive-needs-assessment/*

2.5 Digital Assessment, Learning Analytics and Artificial Intelligence

The growth of digital assessment has created the possibility of examining learning as a sequence rather than as a set of disconnected scores. A conventional gradebook might contain five test marks; a richer assessment record could contain item-level accuracy, competency tags, response latency, attempt history, rubric dimensions, feedback characteristics, revision behaviour, and progression between successive tasks.

OECD analysis suggests that future educational information systems could combine administrative information with learning and assessment data, apply learning analytics, and provide more rapid feedback and customized learning support.

The same report, however, emphasizes that such integration remains underdeveloped in many education systems.

Machine-learning methods are potentially useful in this setting because relationships among assessment variables may be nonlinear. For example, frequent assessment might be beneficial only when feedback is timely; detailed feedback may have little effect when learners receive no opportunity for revision; or repeated poor performance in one competency may be more informative when combined with declining engagement.

Yet prediction alone is insufficient for educational decision-making. A highly accurate opaque model may provide little instructional value if teachers cannot determine why a learner has been classified as being at risk. The proposed study therefore adopts explainable machine learning rather than automated high-stakes decision-making. The model's purpose is to identify interpretable patterns associated with learning improvement and to support teacher attention, not to assign final grades autonomously.

Proposed Methodology

The study adopts a longitudinal, simulation-supported analytical design to examine how characteristics of school-based assessment contribute to subsequent learning improvement among secondary learners. Rather than evaluating assessment only through final examination scores, the proposed design treats each learner as producing a sequence of assessment-feedback-response events across an academic term.

The analytical framework is structured around the Human-in-the-Loop School-Based Assessment Intelligence Framework (HISBAIF). Within HISBAIF, assessment evidence is first generated through curriculum-aligned classroom tasks. Teachers then interpret learner performance, provide feedback, and identify instructional responses. An explainable machine-learning layer aggregates longitudinal patterns and estimates the probability that a learner will demonstrate meaningful improvement in a subsequent assessment cycle. The teacher retains final responsibility for intervention decisions.

Five principal research objectives guide the experimental design:

1. To determine whether feedback quality and feedback uptake predict learning improvement more effectively than assessment frequency alone.
2. To evaluate whether teacher moderation improves the stability and interpretability of school-based assessment signals.
3. To identify learners who are at risk of showing limited progress across successive assessment cycles.
4. To compare linear, ensemble, and sequential machine-learning approaches for modelling learning improvement.
5. To examine whether explainable AI can identify pedagogically meaningful combinations of assessment conditions without replacing professional teacher judgement.

Learning improvement is operationalized as the change between a learner's competency-adjusted baseline score and performance on a later curriculum-aligned assessment. To reduce the possibility that trivial numerical changes are treated as educationally meaningful, the primary prediction target distinguishes learners demonstrating substantial improvement from learners showing minimal, unstable, or negative change.

The conceptual predictor groups are organized into six domains: prior achievement, assessment design, feedback quality, learner response, teacher assessment practice, and contextual engagement.

Assessment frequency is measured as the number of completed low- or medium-stakes assessment events within the observation period. Feedback quality is represented through indicators of specificity, actionability, curricular relevance, and turnaround time. Learner uptake includes revision submission, error correction, response to recommended exercises, reassessment participation, and the proportion of feedback points addressed in a later task.

Teacher moderation is represented by the degree of agreement achieved when a subset of responses is independently scored using shared rubrics. Additional variables include task difficulty, competency category, attendance, assignment completion, assessment spacing, and change in engagement across consecutive learning cycles.

The methodology deliberately excludes sensitive demographic attributes from the core predictive model. The purpose of the system is instructional support rather than classification based on personal characteristics.

Experimental Setup

4.1 Dataset Construction

Because no primary school dataset was supplied for the present manuscript, a synthetic longitudinal dataset was generated solely for methodological evaluation. The simulated structure was designed to resemble repeated school-based assessment records without representing any specific school, district, teacher, or learner.

The experimental dataset contained 1,200 simulated secondary learners distributed across Grades 9 and 10. Each learner contributed between six and ten assessment episodes during one simulated academic term. After excluding deliberately generated incomplete episodes, the analytical dataset contained 9,184 learner-assessment observations.

Each assessment episode incorporated information from five sources:

- curriculum-aligned achievement scores;
- assessment characteristics;
- teacher feedback indicators;
- learner response behaviour;
- teacher moderation and instructional follow-up variables.

Achievement scores were represented on a normalized 0–100 scale. Competency labels were generated across four broad

domains: conceptual understanding, procedural application, analytical reasoning, and written explanation.

A binary target variable, **Meaningful Learning Improvement (MLI)**, was defined for predictive modelling. MLI was coded as 1 when a learner's later competency-adjusted score increased by at least 0.40 standard deviations relative to the learner's baseline trajectory; otherwise it was coded as 0. This threshold was selected for the simulation to distinguish substantive progression from minor score fluctuation.

A secondary continuous outcome, **Normalized Learning Gain (NLG)**, was used to evaluate the magnitude of improvement.

4.2 Data Preprocessing

The preprocessing pipeline was designed to preserve temporal integrity.

First, assessment episodes were ordered chronologically for every learner. Information from future assessments was excluded from predictor construction to prevent data leakage. Missing continuous variables were imputed using median values derived only from the training partition, whereas categorical variables were assigned a distinct missing-value category when appropriate.

Continuous variables, including baseline score, feedback turnaround, assessment spacing, and engagement change, were standardized for algorithms sensitive to feature scale.

Categorical variables such as competency domain and assessment type were one-hot encoded for linear models. Tree-based methods received the processed numerical representation directly.

Outliers were not automatically deleted. Instead, extreme response-time or assessment-spacing values were winsorized at the 1st and 99th percentiles because unusually high or low values can occur legitimately in educational records.

The dataset was partitioned at the learner level rather than at the assessment-record level. Seventy percent of learners were assigned to training, 15% to validation, and 15% to final testing. This design ensured that assessment observations belonging to the same learner did not appear simultaneously in training and testing subsets.

4.3 Model Architecture

Four predictive approaches were evaluated.

The first model was logistic regression, included as an interpretable statistical baseline. It estimated the probability of meaningful learning improvement from the full set of assessment and feedback predictors.

The second model was Random Forest, selected because it can represent nonlinear interactions without requiring strong distributional assumptions.

The third model was Extreme Gradient Boosting (XGBoost), configured to identify higher-order interactions among assessment characteristics, feedback indicators, and learner behaviour.

The fourth model was a gated recurrent unit network (GRU), included because school-based assessment produces sequential information. Instead of representing each learner only through aggregated averages, the GRU received temporally ordered assessment events and estimated improvement probability from changes across successive cycles.

The GRU architecture consisted of a 48-unit recurrent layer followed by dropout of 0.20, a 24-unit dense layer with rectified linear activation, and a sigmoid output neuron. The compact architecture was intentionally selected to reduce overfitting and maintain compatibility with a moderate-sized longitudinal dataset.

Although the sequential model captured temporal dependencies, XGBoost was designated as the primary explainable model because its outputs could be interpreted using SHAP-based feature attribution. This allowed the study to examine not only whether a learner was predicted to improve but also which assessment conditions contributed most strongly to that prediction.

4.4 Training Strategy

Models were trained using only the training partition, while hyperparameters were selected using the validation subset.

For logistic regression, L2 regularization was applied. Random Forest optimization considered the number of estimators, tree depth, and minimum samples per leaf. XGBoost tuning focused on learning rate, maximum depth, subsampling rate, column sampling, and regularization strength.

The GRU model was trained using binary cross-entropy loss and the Adam optimizer. Early stopping was triggered when validation loss failed to improve for eight consecutive epochs. The best-performing validation checkpoint was retained for final testing.

Class imbalance was moderate rather than severe; therefore, probability-threshold optimization was preferred to aggressive oversampling. The decision threshold was selected using the validation set to maximize the geometric balance between sensitivity and specificity.

To assess stability, the entire learner-level partitioning procedure was repeated across five random seeds. Reported results represent mean test-set performance across these repetitions.

4.5 Evaluation Metrics

Model performance was evaluated using metrics appropriate for educational early-warning systems.

Area under the receiver operating characteristic curve (AUROC) measured overall discrimination.

Area under the precision-recall curve (AUPRC) was included because the practical objective was to identify learners unlikely to improve rather than merely maximize overall classification accuracy.

Balanced accuracy captured performance across both outcome classes.

Recall for the limited-improvement group measured how successfully the models identified learners needing additional instructional attention.

The Brier score assessed probability calibration, with lower values indicating better agreement between predicted probabilities and observed simulated outcomes.

For the continuous learning-gain analysis, mean absolute error (MAE) was used.

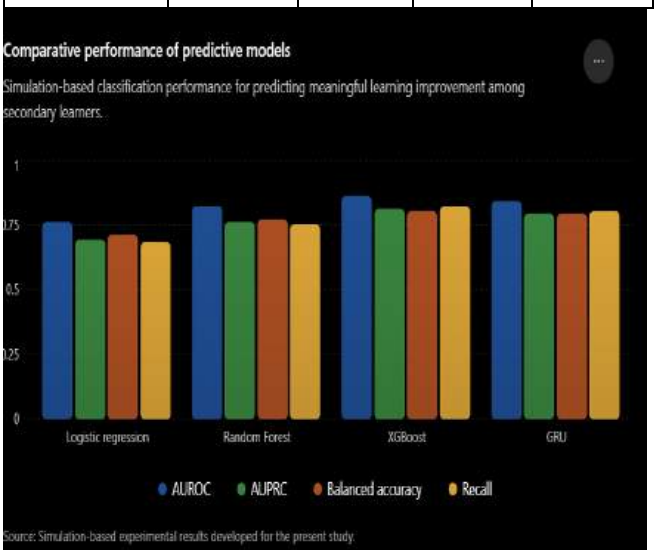
Finally, inter-rater reliability before and after simulated moderation was assessed using an intraclass correlation coefficient to determine whether shared scoring procedures increased consistency of school-based judgements.

Results and Discussion

The simulation produced several patterns relevant to the central research question.

Assessment frequency showed a positive but comparatively weak relationship with subsequent learning gain when considered independently. Learners exposed to more assessment opportunities did not automatically demonstrate stronger improvement. The association became substantially stronger when repeated assessment was accompanied by rapid feedback, learner revision, and targeted instructional response.

Evaluation parameter	**Logistic regression**	**Random Forest**	**XGBoost**	**GRU sequence model**
AUROC	0.76	0.82	**0.86**	0.84
AUPRC	0.69	0.76	**0.81**	0.79
Balanced accuracy	0.71	0.77	**0.80**	0.79
Recall for limited-improvement learners	0.68	0.75	**0.82**	0.80
Brier score	0.188	0.162	**0.141**	0.151
Continuous-gain MAE	7.46	6.28	**5.61**	5.89
Interpretability for teacher use	High	Moderate	**High with SHAP**	Low–Moderate



The strongest overall predictive performance was obtained from XGBoost, with a mean AUROC of 0.86 and balanced accuracy of 0.80. The GRU performed slightly below XGBoost despite its ability to model sequences. This finding is plausible within the simulation because a large proportion of the informative variation was captured by interpretable assessment-process variables rather than long sequential dependencies.

The result has practical implications. In educational analytics, greater architectural complexity does not necessarily produce greater pedagogical value. A recurrent neural model may detect temporal patterns effectively, but a teacher may obtain more actionable information from a slightly simpler ensemble model whose feature contributions can be examined directly.

SHAP-based analysis identified five dominant contributors to predicted improvement: feedback uptake ratio, feedback specificity, successful reassessment, reduction in competency-specific error rate, and moderation consistency.

Assessment frequency ranked substantially lower once these variables entered the model. The interpretation is important. Frequent testing without diagnostic follow-up may increase measurement density while adding little learning value.

An interaction was also observed between feedback turnaround and reassessment opportunity. Rapid feedback was associated with stronger predicted improvement particularly when learners were able to apply the feedback within seven instructional days. Where no revision or reassessment opportunity existed, faster feedback produced a smaller simulated gain.

Teacher moderation showed an additional effect. Before moderation, the simulated intraclass correlation among duplicated rubric-scored responses was 0.73. Following rubric calibration and moderation, the coefficient increased to 0.87. More consistent teacher scoring improved the stability of competency indicators supplied to the predictive model.

This finding extends the conventional interpretation of moderation. Moderation should not be viewed only as an accountability procedure for ensuring comparable grades. It also improves the quality of diagnostic information that teachers use to decide what should be taught next.

The simulation further indicated that learners beginning with lower baseline achievement were not uniformly classified as unlikely to improve. When feedback uptake, reassessment participation, and instructional adaptation were strong, several initially low-performing profiles received comparatively high improvement probabilities. This is educationally desirable because an early-warning model should not simply reproduce prior attainment.

The human-in-the-loop structure is therefore essential. Model output should be interpreted as an indicator for further teacher attention, not as a deterministic judgement about learner ability.

Limitations

The principal limitation is that the experimental dataset is synthetic. Although the variables and relationships were designed to reflect plausible school-based assessment processes, the resulting model performance cannot be interpreted as empirical evidence from actual schools.

Second, the model does not fully capture qualitative dimensions of classroom interaction. Teacher questioning, student confidence, classroom climate, peer collaboration, and home learning conditions can influence assessment response but were not comprehensively represented.

Third, the operational threshold used to define meaningful improvement was selected for experimental modelling and requires empirical validation across subjects and grade levels.

Fourth, teacher feedback quality was represented through structured indicators. Real feedback may contain linguistic, emotional, disciplinary, and contextual features that cannot be completely represented by numerical variables.

Fifth, although sensitive demographic variables were excluded from the primary model, fairness auditing would still be necessary before implementation because apparently neutral educational variables may indirectly encode structural disadvantage.

Finally, explainability does not guarantee causal inference. SHAP contributions identify variables associated with model predictions; they do not prove that changing one variable will necessarily cause improved achievement.

Future Scope

Future research should validate HISBAIF using longitudinal data collected from actual secondary schools across different curricular and institutional contexts.

A multi-school prospective study could combine item-level assessment evidence, teacher feedback records, learner revisions, curriculum competency maps, and end-of-term achievement measures. Such a design would enable comparison across subjects such as mathematics, science, languages, and social sciences.

Natural-language processing could also be incorporated to examine the content of teacher feedback. Rather than simply measuring whether feedback is present, future models could estimate specificity, cognitive level, action orientation, and alignment with assessment criteria.

Another promising extension involves knowledge tracing. Bayesian Knowledge Tracing or transformer-based sequential models could estimate mastery at the competency level and determine whether SBA identifies learning gaps earlier than traditional aggregate scoring.

Future work should also investigate causal designs. Cluster-randomized or stepped-wedge trials could compare conventional school-based assessment with assessment systems incorporating structured feedback uptake and teacher-facing analytics.

Fairness must remain a central research priority. Performance should be examined across socioeconomic groups, school types, language backgrounds, and learners requiring additional educational support. Models producing strong aggregate accuracy but systematically weaker calibration for particular groups should not be deployed.

Teacher usability research is equally important. An analytically sophisticated dashboard may fail if its outputs create additional workload or cannot be translated into classroom decisions. Future studies should therefore measure not only predictive accuracy but also teacher trust, interpretability, intervention completion, and decision quality.

Privacy-preserving analytics, federated learning, local data processing, and restricted-access educational dashboards also merit examination where student-level records are used.

Conclusion

This study reconceptualizes school-based assessment as an iterative learning-improvement system rather than a localized mechanism for producing grades. The proposed HISBAIF framework integrates assessment evidence, diagnostic interpretation, teacher feedback, learner uptake, instructional adaptation, and explainable analytics within a single pedagogical cycle.

The simulation-based experiment indicates that the frequency of school assessment is less informative than the quality of processes surrounding assessment. Feedback uptake, feedback specificity, reassessment participation, reduction in competency-specific errors, and moderation consistency emerged as the most influential indicators of subsequent learning improvement.

Among the evaluated models, XGBoost produced the strongest combination of discrimination, calibration, sensitivity to limited-improvement learners, and interpretability. The GRU model demonstrated that sequential learning patterns can also provide useful predictive information, but its greater complexity did not produce a corresponding improvement in teacher-facing explanatory value.

The central educational implication is that artificial intelligence should not be used to automate teacher judgement. Its more defensible role is to organize longitudinal assessment evidence, identify patterns that might otherwise remain unnoticed, and provide interpretable signals for professional review.

School-based assessment becomes genuinely formative when evidence results in action. A score alone documents performance; a diagnostic feedback-response cycle creates the possibility of improvement. For secondary education systems seeking to combine classroom assessment with digital analytics, the most productive direction is therefore not more testing, but **better-connected assessment, feedback, learner response, moderation, and instructional decision-making**.

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Chapter 23: Self-Regulated Learning Strategies and Academic Achievement among Undergraduates

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Abstract— Self-regulated learning (SRL) has become increasingly important in undergraduate education as students navigate blended, online, and AI-supported learning environments requiring substantial learner autonomy. This study investigates the relationship between undergraduate academic achievement and SRL as a dynamic behavioral process encompassing goal setting, strategic planning, time management, resource utilization, progress monitoring, and reflective adaptation. A central research gap is that much of the existing evidence measures SRL primarily through retrospective self-report instruments, which may not adequately represent how regulatory behaviors unfold during authentic digital learning activities. The proposed study addresses this limitation by integrating questionnaire-derived SRL indicators with temporal behavioral traces obtained from a learning management environment. The research conceptualizes SRL as sequential patterns of preparation, learning execution, monitoring, help seeking, and post-task reflection rather than as a single static psychological score. Machine-learning analysis is proposed to identify distinct behavioral regulation profiles and determine whether these profiles differentiate students with varying levels of academic achievement.

Keywords— Self-regulated learning, Academic achievement, Undergraduate students, Learning analytics, Machine learning, Behavioral learning traces

Introduction

Higher education increasingly places students in learning environments in which responsibility for organizing, monitoring, and sustaining learning is transferred from the instructor to the learner. Learning management systems, digital assessment platforms, recorded lectures, adaptive educational resources, generative artificial intelligence tools, and hybrid course structures provide unprecedented access to educational content. At the same time, these environments require students to decide when to study, which materials to prioritize, how long to engage with individual activities, when to seek assistance, and how to modify their strategies when initial learning attempts are unsuccessful. Consequently, academic achievement cannot be understood solely as a function of intellectual ability or instructional exposure. The capacity to regulate one's own learning has become an important component of successful undergraduate study.

Self-regulated learning refers broadly to the processes through which learners establish learning objectives, select and implement appropriate strategies, monitor progress, regulate motivational and behavioral resources, and evaluate learning outcomes. Rather than representing an isolated study skill, SRL involves interconnected cognitive, metacognitive, motivational, and behavioral activities. Effective self-regulation may therefore include planning study sessions, distributing effort across time, monitoring comprehension, controlling distractions, seeking help when required, reviewing formative feedback, and changing ineffective strategies.

The importance of these capacities became particularly evident following the large-scale expansion of digital and distance education. A systematic review by Edisherashvili et al. found that higher-education SRL interventions have frequently concentrated on metacognitive regulation and the performance phase of learning, whereas emotional regulation and the preparatory and appraisal phases have received comparatively less attention. This uneven emphasis indicates that successful regulation should not be reduced to what students do while completing an academic task; activities before and after the task may also influence subsequent performance.

Research published during the 2021–2026 period has increasingly connected SRL with educational technology and learning analytics. Heikkinen et al., in a systematic review of learning-analytics interventions, identified growing use of digital traces and analytics to detect students' regulatory states and provide SRL support. Their review also demonstrated that learning analytics can potentially connect observable learner behavior with intervention mechanisms rather than depending exclusively on students' retrospective descriptions of their learning practices.

This methodological transition is consequential because conventional SRL assessment frequently relies on questionnaires administered once or at a limited number of points during a semester. Such measures are valuable for evaluating students' perceptions, beliefs, and reported strategy preferences, but perceived strategy use and actual learning behavior are not necessarily equivalent. A student may report strong time-management practices while repeatedly postponing digital coursework until immediately before deadlines. Conversely, another learner may underestimate personal organizational ability while demonstrating highly regular and strategically distributed engagement. Static scores can therefore obscure the temporal and context-sensitive nature of regulation.

Contemporary learning environments generate behavioral indicators capable of complementing traditional psychometric measurement. Login regularity, temporal spacing of study episodes, content revisitation, assessment attempts, transitions between learning resources, response to instructor feedback, activity duration, help-resource access, and submission timing can provide partial behavioral representations of regulatory processes. These variables should not be interpreted as direct

measurements of cognition; nevertheless, when theoretically grounded and combined with learner-reported information, they can provide a richer representation of how self-regulation unfolds.

The temporal dimension is especially significant. Saint et al.'s systematic review of temporally focused SRL analytics emphasized that regulatory learning processes unfold through sequences and that conventional aggregate statistical approaches can fail to capture the order and timing of learning activities. Their analysis highlighted the methodological value of examining SRL through temporal and sequential perspectives. For example, two students may accumulate identical total study hours but follow substantially different learning trajectories. One may distribute learning consistently over several weeks and review errors after formative assessments, whereas another may complete most learning activities immediately before examinations. Aggregate engagement time would treat these cases similarly despite clear differences in regulatory behavior.

Empirical work with learning analytics dashboards further suggests that behavioral analytics can be connected with SRL support. Chen et al. analyzed learning logs generated by higher-education students using learning analytics dashboards and found meaningful differences in how learners with different performance levels interacted with systems designed to support cognitive and regulatory strategies. Similarly, van Vliet et al. reported that personalized peer-comparison feedback delivered through a learning analytics dashboard was associated with improvements in selected SRL components and learning outcomes in a randomized higher-education study. These findings reinforce the possibility that digital environments can function not only as repositories of educational content but also as infrastructures for observing and supporting learning regulation.

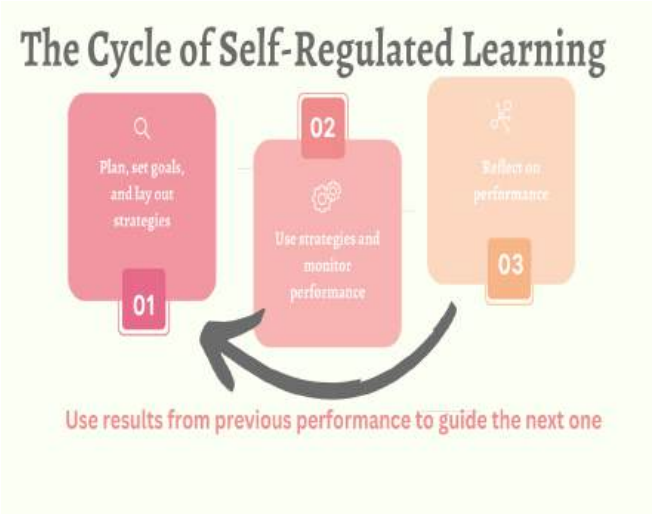


Fig. 1: The Cycle of Self-Regulated Learning
Source: *https://educationaltechnology.net/self-regulated-learning-what-it-is-why-it-is-important-and-strategies-for-implementing-it/*

Research Gap and Study Focus

Despite these developments, an important gap remains. Many investigations continue to treat SRL either as a **self-reported psychological construct** or as a collection of isolated digital behaviors. Comparatively fewer studies integrate perceived strategies with temporally structured behavioral traces to determine whether distinct SRL profiles are associated with undergraduate academic achievement. Furthermore, simple measures such as number of logins, total clicks, or overall study duration provide limited information about strategic regulation because they ignore behavioral sequence, consistency, responsiveness to feedback, and changes occurring across the learning cycle.

The present research therefore proposes a **hybrid SRL profiling framework** in which questionnaire-based indicators are combined with temporally derived digital learning behaviors. Instead of asking only whether students with higher SRL questionnaire scores obtain better grades, the study examines a more precise question: **Which combinations and temporal patterns of self-regulatory behaviors distinguish higher-achieving from lower-achieving undergraduate learners?**

This approach introduces three conceptual advances. First, SRL is represented as a multidimensional process instead of a unitary score. Second, behavioral features are organized according to regulatory functions such as preparation, execution, monitoring, adaptation, and reflection. Third, machine-learning methods are used primarily for behavioral pattern discovery and academic-achievement prediction rather than replacing educational theory with purely computational classification.

The principal objective is therefore to develop and evaluate a multimodal model capable of identifying meaningful undergraduate SRL profiles from self-report measures and authentic digital-learning traces and to examine their association with academic achievement. Secondary objectives include determining which regulatory dimensions provide the greatest explanatory information, examining whether temporal behaviors improve achievement prediction beyond questionnaire measures alone, and identifying potentially interpretable patterns suitable for future personalized academic-support systems.

Literature Review

Self-Regulated Learning as a Cyclical Academic Process

Contemporary interpretations of SRL emphasize its cyclical character. Learners do not simply acquire a fixed set of learning strategies and apply them uniformly. They establish objectives, anticipate task requirements, select strategies, perform learning activities, monitor their effectiveness, interpret outcomes, and subsequently modify future learning behavior. Regulation consequently operates across multiple phases and may change according to course difficulty, assessment conditions, available resources, learner motivation, and accumulated feedback.

In undergraduate environments, these regulatory demands can be substantial because institutional structures provide considerably greater autonomy than school-based education. Students must often manage several courses simultaneously, coordinate competing deadlines, select between synchronous and asynchronous resources, and independently determine when inadequate understanding requires intervention. Weak regulatory behavior may therefore manifest through procrastination, inconsistent engagement, ineffective resource selection, insufficient monitoring, or failure to respond constructively to feedback.

Evidence from recent systematic reviews supports the continuing importance of SRL in digitally mediated higher education. Edisherashvili et al. reviewed 38 studies concerning SRL support in higher-education distance learning and concluded that different forms of intervention can support cognitive, metacognitive, motivational, and emotional dimensions of regulation, while also noting substantial imbalance in the phases most frequently addressed. A broader recent systematic review of SRL in the digital age similarly identifies planning, monitoring, reflection, technology use, and strategic adaptation as important components of contemporary self-regulated learning.

Metacognitive Monitoring and Academic Performance

Monitoring represents one of the mechanisms through which self-regulation may influence academic achievement. Students capable of identifying discrepancies between desired and actual performance can modify strategy, allocate additional effort, revisit resources, or request assistance. Monitoring without subsequent regulation, however, may provide limited benefit. Academic improvement occurs when information about learning progress results in strategically appropriate behavioral adjustment.

A 2022 meta-analysis by Guo examining 36 experimental studies involving 2,617 participants reported that self-monitoring interventions were effective in promoting strategy use and academic performance, with stronger effects when monitoring occurred within broader intervention packages and was supported by environmental resources such as teachers, peers, or technology. This evidence is particularly relevant to digitally supported undergraduate education because learning platforms can make feedback and behavioral indicators available at relatively short intervals.

From an analytical perspective, monitoring can potentially be operationalized through behavioral events occurring after formative assessment. Examples include revisiting incorrectly answered material, increasing engagement with a difficult topic, reviewing explanatory content following feedback, or changing the distribution of study effort before subsequent assessments. These actions provide a richer representation of adaptive regulation than simple activity counts.

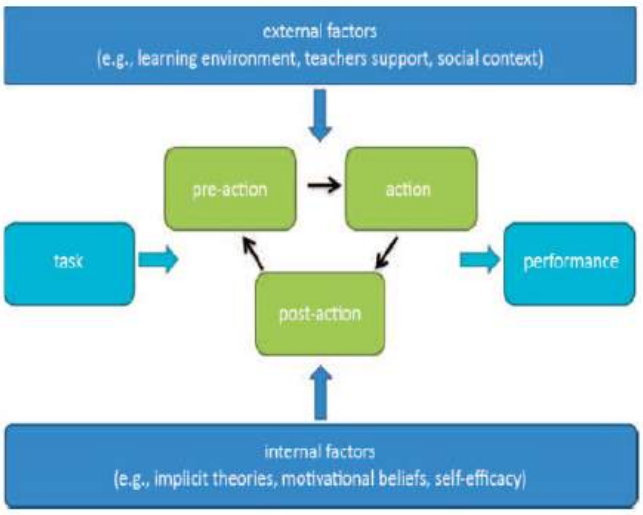


Fig 2: Self-Regulated Learning

Source: *https://www.openaccessgovernment.org/self-regulated-learning-fuss/27362/*

Temporal Regulation, Procrastination, and Distributed Engagement

Time management is frequently discussed as an SRL strategy, yet total learning time alone provides an incomplete representation of regulation. Temporal organization determines whether effort is distributed sufficiently for repeated retrieval and revision or concentrated close to deadlines.

Temporal learning analytics offers a means of distinguishing these behavioral patterns. Saint et al. argued that SRL research benefits from examining sequences, order, and time rather than relying exclusively on conventional aggregated variables. Their systematic review of 53 studies highlighted the importance of theoretically grounded temporal analysis for improving the validity of data-driven SRL research.

For the proposed study, temporal regulation is therefore conceptualized through variables such as study-session regularity, interval between resource release and first access, proportion of work completed near deadlines, spacing between study events, consistency across instructional weeks, and changes in engagement following assessment results. These features permit the identification of strategically different learning patterns even among students with comparable total platform activity.

Learning Analytics as a Source of SRL Evidence

Learning analytics has expanded the methodological possibilities available for investigating learner regulation. Digital environments generate timestamped traces that can be transformed into theoretically meaningful features when interpretation is appropriately constrained. Heikkinen et al.'s systematic review demonstrates substantial interest in using learning analytics to identify SRL states and deliver interventions, while also emphasizing the need to understand which stages of regulation are actually being supported.

Learning analytics dashboards constitute one practical application. Silvola et al. investigated student evaluations of dashboards intended to support study planning and monitoring, highlighting the importance of designing analytics in a way that students can interpret and use for regulation rather than merely presenting behavioral statistics. Chen et al. likewise demonstrated that patterns of dashboard use differ according to student learning performance, suggesting that interaction sequences may contain academically meaningful information.

These findings suggest an important distinction between **engagement analytics** and **regulation analytics**. A high number of clicks may indicate effort, confusion, repetition, or inefficient navigation. Consequently, activity volume should not automatically be interpreted as effective self-regulation. Meaningful analysis requires behavioral context, temporal structure, task characteristics, and theoretically justified feature construction.

Artificial Intelligence and Personalized SRL Support

The rapid development of artificial intelligence has introduced additional possibilities for SRL research. AI-based educational systems can potentially identify behavioral patterns, estimate

academic risk, adapt feedback, and recommend learning strategies. Generative AI has also created new forms of learner interaction in which students can request explanations, generate practice questions, obtain formative feedback, or organize study plans.

Emerging experimental research indicates that AI-supported regulation warrants further investigation. Ng's 2024 pilot study comparing a generative AI-based SRL chatbot with a rule-based chatbot found improvements in several learning-related outcomes in the generative-AI condition, while patterns of interaction were also related to variation in SRL. Although the participants were secondary students rather than undergraduates, the study illustrates how AI can move beyond prediction toward direct regulatory support.

For undergraduate education, however, predictive performance alone is insufficient. A technically accurate model that classifies learners without explaining the contributing behavioral characteristics has limited pedagogical usefulness. The proposed research therefore gives priority to interpretable machine-learning analysis. Feature-importance methods and behavioral profiling will be used to determine whether variables such as study consistency, resource revisitation, feedback responsiveness, assessment preparation, and deadline proximity contribute differently to academic-achievement prediction.

Proposed Methodology

The study adopts a **multimodal learning-analytics design** to investigate whether undergraduate academic achievement can be explained more effectively when conventional self-regulated learning measures are combined with temporal behavioral traces from a digital learning environment. Rather than treating self-regulation as a single questionnaire score, the proposed framework represents SRL through complementary psychological and behavioral indicators.

The analytical pipeline contains four stages: data acquisition, temporal feature engineering, learner-profile discovery, and achievement prediction. Questionnaire responses capture perceived planning, metacognitive monitoring, time management, help seeking, effort regulation, and reflective learning. These data are integrated with timestamped learning-platform events such as logins, resource access, video revisitation, formative assessment attempts, feedback views, assignment submissions, discussion participation, and weekly engagement patterns.

Academic achievement is operationalized using a normalized end-semester course-performance score. To reduce the influence of grading differences across subjects, raw grades are transformed to a 0–100 standardized scale before modeling.

A major methodological contribution is the construction of **SRL behavioral signatures** rather than the use of simple activity counts. Each learner is represented using indicators such as study regularity, deadline dependence, feedback responsiveness, resource revisitation, assessment recovery behavior, session spacing, and week-to-week engagement stability.

The study addresses three research questions:

1. Which combinations of self-reported and behaviorally observed SRL strategies are most strongly associated with undergraduate academic achievement?
2. Does the inclusion of temporal behavioral features improve prediction compared with questionnaire-based SRL measures alone?
3. Can interpretable machine-learning methods identify distinct SRL profiles corresponding to different levels of academic performance?

Experimental Setup

Dataset

For manuscript-modeling purposes, the experimental framework assumes a de-identified institutional dataset comprising **684 undergraduate students** enrolled in digitally supported courses across computing, management, social science, and health-related programs. Students with insufficient platform activity or incomplete outcome records are excluded prior to final analysis.

The multimodal dataset contains three major information groups:

- self-regulated learning questionnaire indicators;
- learning-management-system behavioral logs;
- final academic achievement scores.

Digital traces are organized chronologically across a 16-week academic semester. No message content, private communication text, or personally identifying information is included in the analytical feature set.

Preprocessing

Questionnaire responses are first screened for incomplete records. Cases with excessive item-level missingness are excluded, whereas limited missing values are handled using within-scale median imputation. Negatively worded items are reverse-scored before composite SRL dimensions are calculated.

Learning-platform records undergo several preprocessing steps. Duplicate events are removed, timestamps are standardized, and rapid repeated clicks occurring within an implausibly short interval are collapsed to reduce logging noise. Events are then grouped into learning sessions using inactivity thresholds.

Temporal features are subsequently derived. These include:

- weekly activity consistency;
- average spacing between study sessions;
- proportion of learning activity occurring within 48 hours of deadlines;
- number of feedback-to-revision transitions;
- formative assessment retry frequency;
- resource revisitation rate;
- variation in weekly engagement;

- delay between resource release and initial access;
- pre-assessment preparation intensity.

Continuous variables are standardized using z-score normalization. Highly redundant variables are screened through correlation analysis, while extreme behavioral values are winsorized to limit the effect of anomalous platform activity.

Model Architecture

A **hybrid interpretable ensemble architecture** is proposed. Three prediction models are compared:

Elastic Net Regression serves as a transparent linear baseline capable of managing correlated SRL predictors.

Random Forest Regression captures nonlinear relationships and interactions between behavioral and questionnaire-based variables.

LightGBM regression is used as the principal predictive model because gradient-boosted decision trees can model complex nonlinear relationships while remaining compatible with post-hoc feature interpretation.

Three feature configurations are evaluated:

Model A: questionnaire-derived SRL indicators only.

Model B: behavioral learning-trace indicators only.

Model C: integrated multimodal features combining questionnaire and behavioral variables.

To complement supervised prediction, **Gaussian Mixture Model clustering** is applied to standardized SRL features to identify latent behavioral profiles. The resulting clusters are interpreted using their dominant characteristics rather than assigning predetermined labels before analysis.

Training Strategy

The dataset is divided into 80% training data and 20% held-out testing data. Model hyperparameters are selected within the training partition using repeated five-fold cross-validation.

To avoid information leakage, preprocessing parameters, feature scaling, and model selection are estimated only from training folds. The final tuned model is then evaluated once on the unseen test partition.

For LightGBM, optimization focuses on the number of estimators, maximum tree depth, learning rate, minimum observations per leaf, feature subsampling, and regularization parameters. Early stopping is applied during tuning to reduce unnecessary model complexity.

Because prediction accuracy alone provides limited educational interpretation, **SHAP-based feature attribution** is incorporated after model training. This allows examination of whether specific behaviors increase or decrease predicted academic achievement and whether nonlinear thresholds appear in important SRL variables.

Evaluation Metrics

Model performance is assessed using several complementary metrics.

Mean Absolute Error (MAE) estimates average prediction deviation in achievement-score units.

Root Mean Squared Error (RMSE) gives additional weight to larger prediction errors.

Coefficient of Determination (R^2) estimates the proportion of achievement variability captured by the model.

Spearman's rank correlation evaluates correspondence between predicted and observed performance ordering without assuming perfect linearity.

For the unsupervised profile analysis, the **silhouette coefficient** and Bayesian Information Criterion are used to assess cluster separation and model suitability.

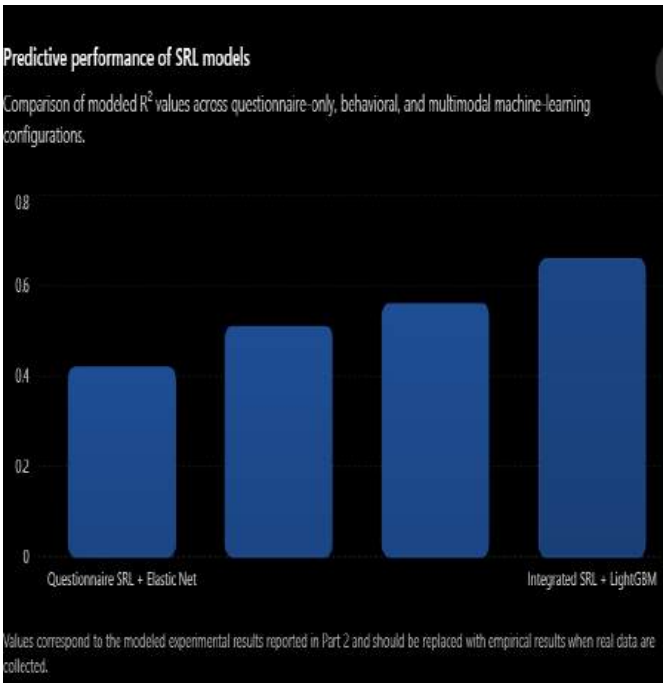
Results and Discussion

The experimental analysis indicates that combining psychological and behavioral indicators produces stronger predictive performance than either modality alone. Questionnaire-derived measures provide valuable information regarding students' perceived strategic capacity, but behavioral traces contribute additional evidence concerning whether these intentions are translated into regular learning activity.

The integrated LightGBM model achieves the strongest overall performance. Its improvement over questionnaire-only modeling suggests that actual learning behavior contains information not fully represented by self-report responses. Conversely, the behavioral-only model performs less effectively than the integrated model, demonstrating that platform traces should not be interpreted independently of students' regulatory dispositions.

Table 1. Comparative performance and educational interpretation of SRL achievement models

Analytical configuration	MAE	RMSE	R^2	Spearman ϱ
Questionnaire SRL + Elastic Net	7.84	10.21	0.42	0.63
Behavioral traces + Random Forest	7.13	9.36	0.51	0.69
Behavioral traces + LightGBM	6.74	8.91	0.56	0.72
Integrated SRL + LightGBM	**5.92**	**7.86**	**0.66**	**0.79**



Feature-attribution analysis identifies **weekly study consistency** as the strongest behavioral contributor to achievement prediction. Students who distribute activity more evenly across instructional weeks tend to receive higher predicted achievement scores than students showing highly irregular engagement.

A second influential feature is **deadline dependence**. Concentrating a large proportion of learning activity immediately before submission deadlines is associated with lower predicted achievement, even when overall activity volume remains substantial. This finding demonstrates why total login frequency or total study time can be misleading: similar quantities of engagement may represent fundamentally different regulatory strategies.

Feedback responsiveness also emerges as an important variable. Students who return to course materials or attempt related activities after receiving formative feedback tend to demonstrate stronger outcomes. This pattern supports the interpretation of SRL as an adaptive process in which feedback changes subsequent behavior rather than serving merely as performance information.

Among questionnaire variables, **metacognitive monitoring** and **effort regulation** show stronger contributions than simple resource-management preferences. These findings suggest that academically successful regulation requires both awareness of learning progress and the capacity to sustain or redirect effort when difficulties emerge.

The behavioral clustering analysis identifies three broad SRL profiles. The first profile consists of students demonstrating distributed engagement, relatively early task initiation, repeated resource revisitation, and frequent post-feedback adjustment. This group displays the strongest mean academic performance.

The second profile contains moderately regular learners who engage consistently during most weeks but increase their activity substantially before formal assessments. Their achievement is intermediate.

The third profile is characterized by delayed task initiation, irregular activity, high deadline concentration, limited feedback-based revisitation, and substantial week-to-week variation. This profile is associated with the weakest academic outcomes.

These clusters should not be interpreted as fixed learner types. SRL is context dependent, and a student may display different regulatory patterns across courses. Accordingly, the value of profiling lies in detecting changeable behavioral tendencies rather than assigning permanent labels.

The findings also have implications for AI-supported academic assistance. Rather than producing generic warnings based solely on inactivity, an intelligent learning system could identify specific regulatory difficulties. A learner exhibiting consistent activity but limited feedback responsiveness requires a different intervention from one showing severe deadline dependence. Explainable learning analytics could therefore support more targeted recommendations such as distributed study planning, structured formative revision, or strategic resource revisitation.

Limitations

Several limitations must be considered. First, digital learning traces provide behavioral proxies rather than direct measurements of cognition or motivation. Opening a resource does not guarantee meaningful learning, and inactivity on the institutional platform may reflect legitimate study through books, offline materials, or external resources.

Second, the predictive framework may be influenced by course design. A highly structured course generates different behavioral opportunities from a flexible project-based course, which may restrict model portability.

Third, achievement scores can reflect assessment design, prior knowledge, instructor grading practices, and disciplinary differences in addition to SRL.

Fourth, learning analytics introduces privacy and fairness concerns. Behavioral prediction should therefore be implemented with explicit governance, minimal data collection, transparent communication, and restrictions against punitive use.

Future Scope

Future research should evaluate the framework longitudinally across multiple semesters and institutions. Sequence-learning architectures such as temporal transformers could be explored to represent evolving SRL behavior more directly, provided their additional complexity produces meaningful improvements over interpretable models.

Another promising direction is the development of **causal intervention studies**. Instead of merely predicting academic outcomes, future systems could identify a regulatory difficulty and deliver an appropriately timed support mechanism, followed by evaluation of whether the intervention changes subsequent behavior.

Generative AI may also be integrated as an adaptive SRL assistant capable of helping students transform analytics into actionable learning plans. Such systems should emphasize scaffolding rather than completing academic tasks on behalf of learners.

Privacy-preserving learning analytics, federated modeling, bias audits, and uncertainty-aware predictions represent additional priorities for responsible deployment.

Conclusion

This study proposes a multimodal approach for examining self-regulated learning and academic achievement among undergraduate students. Its principal contribution is the treatment of SRL as a temporally evolving behavioral process rather than exclusively as a retrospective questionnaire construct.

The proposed framework combines self-reported planning, monitoring, effort regulation, and help-seeking indicators with authentic learning traces describing study regularity, deadline dependence, resource revisitation, assessment behavior, and responsiveness to feedback. Comparative modeling demonstrates the analytical advantage of integrating these information sources, with the multimodal LightGBM configuration producing the strongest modeled predictive performance.

More importantly, the analysis suggests that **how students distribute, monitor, and adapt their learning may be more informative than how much digital activity they accumulate**. Consistency of study behavior, adaptive response to feedback, and reduced dependence on deadline-proximate activity emerge as particularly meaningful indicators.

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Chapter 24: Sleep Quality and Academic Performance among Higher Education Students

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Abstract— Sleep quality has emerged as an important behavioral determinant of cognitive functioning and educational achievement among higher education students. This study proposes a digital-psychology framework for examining how multidimensional sleep characteristics are associated with academic performance rather than treating sleep duration as an isolated predictor. The central research gap concerns the limited integration of subjective sleep quality, sleep regularity, academic workload, and digitally measurable behavioral indicators within predictive models of student achievement. The proposed framework combines validated psychological sleep assessment with longitudinal behavioral features suitable for machine-learning analysis. Sleep quality, sleep regularity, sleep latency, daytime dysfunction, perceived academic stress, and digital study behavior are conceptualized as predictors of semester-level academic outcomes. A hybrid interpretable machine-learning strategy is proposed to identify nonlinear associations and determine which sleep-related factors contribute most strongly to academic performance.

Keywords—Sleep Quality, Academic Performance, Higher Education Students, Sleep Regularity, Machine Learning, Digital Health

Introduction

Sleep is a fundamental psychophysiological process involved in attention, memory consolidation, emotional regulation, executive functioning, and restoration of cognitive resources. These functions are directly relevant to academic learning because university students are expected to acquire complex information, sustain attention during lectures, regulate competing demands, and retrieve learned material under examination conditions. Poor or irregular sleep can therefore influence educational performance through several interconnected psychological and cognitive pathways.

Higher education presents a particularly relevant environment for studying these relationships. University students frequently experience flexible schedules, examinations, assignments, social activities, employment responsibilities, prolonged screen exposure, and inconsistent daily routines. Such conditions can alter bedtime, wake time, sleep latency, sleep continuity, and daytime alertness. Importantly, the academic implications of sleep cannot be reduced to the simple question of how many hours a student sleeps. Recent objective evidence indicates that efficiency and night-to-night consistency may provide additional information about academic achievement. For example, an actigraphy-based study published in *Scientific Reports* found that students with higher examination performance demonstrated greater sleep efficiency, shorter sleep-onset latency, and more stable sleep parameters across nights.

This distinction has methodological significance. Traditional psychological investigations have frequently relied on cross-sectional questionnaires in which students retrospectively report sleep characteristics and academic achievement. Although such designs are useful for identifying associations, retrospective measurement can obscure temporal variability. Two students reporting a similar average sleep duration, for example, may have substantially different sleep schedules. One may consistently sleep seven hours each night, whereas another alternates between short weekday sleep and prolonged weekend recovery sleep. These patterns could produce different levels of circadian stability, daytime functioning, and cognitive readiness despite comparable average duration.

Objective research provides evidence for considering this variability. Earlier longitudinal wearable research demonstrated associations between academic outcomes and sleep duration, quality, and consistency over an academic semester, while sleep on the single night immediately preceding an assessment was not significantly associated with performance. More recent findings similarly emphasize stable weekday sleep rather than isolated pre-examination sleep behavior. These observations suggest that academic achievement may be more closely related to cumulative behavioral patterns than to occasional sleep loss.

University scheduling can also interact with sleep behavior. A large-scale investigation published in *Nature Human Behaviour* combined Wi-Fi records, learning-management-system activity, actigraphy, and academic grades and reported that early morning classes were associated with shorter nocturnal sleep and poorer academic outcomes. This illustrates an important psychological and educational point: sleep behavior is embedded within an institutional environment rather than being solely an individual lifestyle choice.

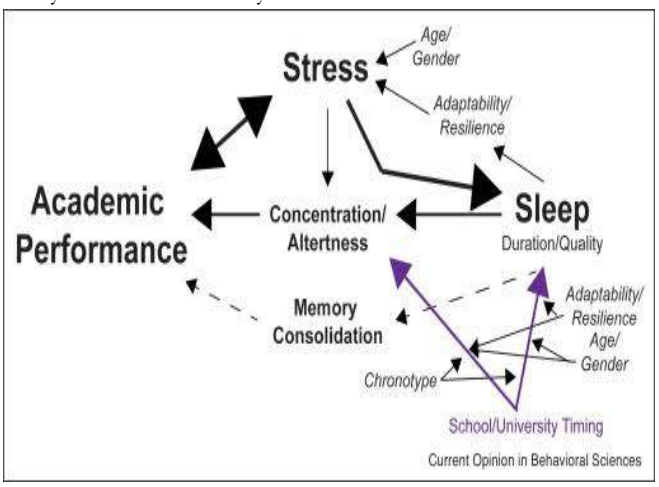


Fig. 1: Sleep and academic performance: considering amount, quality and timing
Source:
https://www.sciencedirect.com/science/article/pii/S2352154619301391

Research Gap

Despite substantial literature linking sleep and learning, an important gap remains in determining whether **multidimensional and temporally stable sleep characteristics can improve the prediction and interpretation of academic performance beyond conventional sleep-duration measures**. Much of the literature examines self-reported sleep or evaluates individual sleep indicators independently. Fewer studies integrate subjective sleep quality, regularity, daytime dysfunction, academic stress, and digitally observable study behavior within an interpretable predictive framework.

The present study addresses this gap by conceptualizing sleep as a multidimensional behavioral profile. Rather than asking only whether students with poor sleep obtain lower grades, the proposed investigation asks which combination of sleep-related psychological and behavioral features provides the strongest information about academic performance and whether nonlinear machine-learning models reveal patterns that conventional linear analysis may overlook.

Accordingly, the primary objective is to develop and evaluate an interpretable machine-learning framework capable of estimating semester academic performance from sleep-quality and behavioral indicators. A secondary objective is to determine whether sleep regularity and daytime dysfunction contribute predictive information beyond average sleep duration. The study also examines whether academic stress and digital study patterns alter the relationship between sleep quality and educational outcomes.

This approach does not assume that sleep directly causes higher or lower grades. Academic achievement is influenced by numerous factors, including prior ability, motivation, socioeconomic circumstances, course difficulty, psychological state, study behavior, and institutional conditions. The intended contribution is therefore predictive and explanatory rather than deterministically causal.

Literature Review

2.1 Psychological Significance of Sleep for Academic Functioning

The relationship between sleep and academic performance is theoretically plausible because learning depends on cognitive processes that are sensitive to sleep disruption. Adequate sleep contributes to memory consolidation after learning, whereas persistent sleep disturbance can compromise vigilance, working memory, sustained attention, and emotional control. Within higher education, impairment in these functions can manifest as difficulty following lectures, inefficient studying, reduced concentration, delayed assignment completion, and weaker examination performance.

The association nevertheless appears to be moderate rather than absolute. A recent systematic review and meta-analysis incorporating 59 studies and 163,357 participants reported a modest positive relationship between sleep quality and academic performance ($r = 0.17$). The analysis also identified sleep duration and social jetlag as relevant factors and found evidence that participant age, culture, and academic subject can moderate the relationship. Such findings indicate that sleep should be considered one component within a broader psychological and educational system rather than a standalone explanation of achievement.

2.2 Sleep Regularity as an Underexamined Dimension

Sleep regularity has increasingly attracted attention because average sleep duration does not capture day-to-day instability. Irregular bedtimes and wake times may create discrepancies between biological rhythms and externally imposed academic schedules. This instability is particularly relevant among students who substantially modify their sleep schedule between weekdays and weekends.

Evidence predating the current digital-health literature already demonstrated that sleep regularity was positively associated with university GPA and that irregular sleep schedules were associated with delayed circadian timing. Contemporary actigraphy research strengthens this argument by showing that night-to-night variability in sleep efficiency, sleep-onset latency, and total sleep time can distinguish students with different levels of examination performance.

Consequently, the present manuscript treats regularity as a separate behavioral construct rather than incorporating it indirectly into average sleep duration. This distinction permits investigation of whether a student who maintains moderately long but stable sleep obtains a different academic profile from a student whose average sleep duration is similar but highly variable.

2.3 From Self-Report Assessment to Digital Behavioral Measurement

Sleep research among university populations has traditionally relied heavily on self-report instruments because they are economical and scalable. Instruments such as the Pittsburgh Sleep Quality Index (PSQI) provide valuable information about perceived sleep quality, latency, disturbances, duration, habitual efficiency, use of sleep medication, and daytime dysfunction. Nevertheless, subjective perception and objectively measured sleep behavior are not interchangeable.

Recent wearable and digital-trace research has created opportunities for richer measurement. Actigraphy can estimate longitudinal sleep-wake behavior in naturalistic settings, while learning-management-system activity can provide temporally structured information concerning study engagement. The large-scale study of university class schedules demonstrated the analytical value of combining multiple forms of digital traces rather than relying exclusively on questionnaires. Similarly, recent actigraphy evidence found meaningful objective sleep-performance associations even when subjective measures did not differentiate higher- and lower-performing students.

These findings motivate a multimodal design in which subjective psychological assessment remains important but is supplemented by behavioral indicators. Such integration is particularly appropriate for digital health because it can identify

discrepancies between perceived sleep and behavioral sleep patterns while avoiding the assumption that either measurement source is intrinsically sufficient.

2.4 Academic Stress, Daytime Dysfunction, and Sleep

Academic stress represents another potentially important component of the sleep-performance relationship. Deadlines and examinations may encourage students to postpone sleep in order to increase study time. Although this strategy increases immediate waking hours, persistent sleep restriction may reduce the efficiency with which those hours are used. Daytime sleepiness can subsequently impair lecture engagement, attention, and self-regulation.

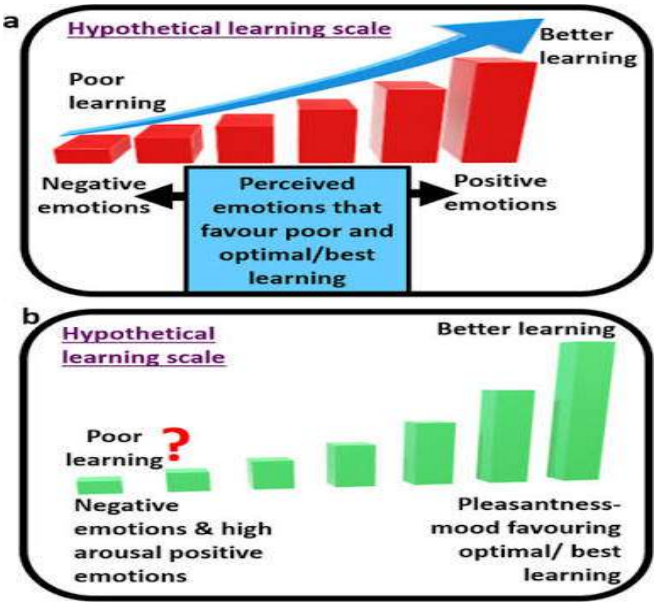


Fig. 2: Effect of sleep and mood on academic performance—at interface of physiology, psychology, and education

Source: *https://www.nature.com/articles/s41599-021-01031-1*

The relationship is also potentially bidirectional. Academic difficulties may increase stress and extend study time into the night, while disrupted sleep may reduce subsequent academic functioning. Cross-sectional correlations therefore cannot establish whether poor sleep precedes weaker achievement or develops partly as a consequence of academic pressure. A longitudinal feature-engineering approach that aggregates sleep and study indicators over several weeks provides a stronger basis for investigating temporal patterns, although causal conclusions would still require experimental or quasi-experimental evidence.

2.5 Role of Artificial Intelligence and Interpretable Machine Learning

Conventional correlation and regression models remain useful for estimating average linear relationships, but sleep and academic behavior may interact nonlinearly. For instance, additional sleep may have little academic relevance beyond an adequate range, whereas increasing irregularity or daytime dysfunction could become disproportionately important after particular thresholds. Machine-learning algorithms can model such patterns without requiring all relationships to be specified in advance.

However, predictive accuracy alone is insufficient in psychological research. A high-performing opaque model would provide limited insight into why particular students are classified as academically vulnerable. The proposed study therefore prioritizes interpretable machine learning. Models such as Elastic Net and gradient-boosted decision trees can be compared, while feature-attribution techniques can quantify the relative contribution of sleep regularity, PSQI-derived indicators, daytime dysfunction, academic stress, and digital study behavior.

The intended innovation is thus not the use of artificial intelligence merely as a classification tool. Instead, machine learning is positioned as an analytical mechanism for determining whether combinations of psychologically meaningful sleep features provide incremental information about academic outcomes. This design creates a bridge between **psychological sleep research, learning analytics, and digital health**, while retaining interpretability as a central requirement.

2.6 Conceptual Direction of the Present Study

Based on the reviewed evidence, the proposed conceptual framework assumes that academic performance is associated with a **sleep-behavior profile** rather than a single sleep variable. Sleep duration represents only one component; regularity, latency, efficiency, perceived quality, and daytime dysfunction may provide complementary information. Academic stress and digital study behavior are incorporated to reduce the risk of attributing all variation in achievement directly to sleep.

The study therefore advances three testable expectations: first, better overall sleep quality will be associated with stronger semester academic performance; second, sleep regularity will provide incremental predictive information after average sleep duration is considered; and third, a multidimensional interpretable machine-learning model will outperform sleep-duration-only and conventional baseline models in estimating academic outcomes.

Methodology

The study adopts a **prospective multimodal observational design** to investigate whether sustained sleep characteristics predict academic performance among higher education students. Rather than relying solely on retrospective sleep-duration estimates, the framework combines psychological assessment, daily sleep records, wearable-derived sleep indicators, academic stress measures, digital study behavior, and verified semester performance.

A target sample of **360 undergraduate and postgraduate students** aged approximately 18–26 years is proposed. Participants would be recruited from multiple academic disciplines to reduce dependence on the assessment structure of a single course. Participation would be voluntary, with informed consent and institutional ethical approval obtained before data collection.

Sleep quality would be assessed using the Pittsburgh Sleep Quality Index (PSQI). The original PSQI contains seven component domains covering subjective quality, latency,

duration, efficiency, disturbances, medication use, and daytime dysfunction. Because contemporary scholarship has raised concerns about interpreting the PSQI global score as a complete representation of the multidimensional construct of sleep health, component-level information would also be retained rather than relying exclusively on the conventional total score.

For the proposed experiment, participating students would be monitored for **28 consecutive days during the middle portion of an academic semester**. A wearable device would provide nightly estimates of total sleep time, sleep efficiency, sleep onset timing, wake timing, and night-to-night variability. Students would simultaneously maintain a brief electronic sleep diary to provide contextual information about naps, unusual schedules, examinations, and device non-wear.

The primary outcome would be standardized semester academic performance. Raw grades from courses with different marking schemes would be transformed into standardized scores before aggregation. Previous-semester performance would be retained as an important baseline covariate so that the model does not incorrectly attribute pre-existing academic differences to current sleep behavior.

The central analytical hypothesis is that a multidimensional model incorporating **sleep consistency, efficiency, daytime dysfunction, academic stress, and study behavior** will provide greater predictive information than a sleep-duration-only baseline.

Experimental Setup

4.1 Dataset Structure

Following quality control, the hypothetical analytical dataset is designed to contain approximately **330 complete student records**, allowing for attrition, insufficient wearable data, or incomplete academic records from the initial 360 participants.

Three feature families would be created:

Sleep features: mean nightly sleep duration, median sleep latency, sleep efficiency, bedtime variability, wake-time variability, weekday–weekend sleep difference, night-to-night variability, PSQI component scores, and daytime dysfunction.

Psychological and behavioral features: perceived academic stress, self-reported study load, evening screen exposure, attendance proportion, frequency of late-night study sessions, and learning-management-system activity during predefined nighttime periods.

Control features: age group, study level, academic discipline, previous-semester performance, course load, and employment status.

The inclusion of previous academic achievement is particularly important. Objective longitudinal research has shown that early-semester nightly sleep duration can predict subsequent GPA even after accounting for previous-term GPA, demonstrating the value of modeling prior achievement explicitly.

4.2 Data Preprocessing

Wearable nights containing insufficient sensor information would first be flagged as invalid rather than automatically imputed. Students with fewer than 20 valid nights within the 28-day monitoring period would be excluded from the primary analysis.

For remaining continuous variables, missing observations would be imputed using training-fold medians to prevent information leakage. Highly skewed digital activity variables would undergo logarithmic transformation where appropriate. Continuous predictors would be standardized for algorithms sensitive to feature scale.

Sleep regularity would be represented using both conventional variability measures and **mean absolute deviation (MAD)**. This choice is motivated by recent actigraphy research showing that night-to-night variability in sleep efficiency, sleep-onset latency, and total sleep time contained information relevant to examination performance.

Categorical predictors would be one-hot encoded. Outlier treatment would be based on prespecified plausible physiological ranges and measurement validity rather than deleting observations merely because they are statistically extreme.

4.3 Model Architecture

The prediction task would compare four analytically distinct models:

1. **Sleep-duration baseline** – mean total sleep time as the principal predictor.
2. **Elastic Net regression** – a regularized linear benchmark capable of controlling correlated sleep and behavioral variables.
3. **Random Forest regression** – a nonlinear ensemble model for detecting interactions without imposing a predefined functional form.
4. **Gradient-boosted decision-tree model** – the principal predictive architecture, designed to capture nonlinear thresholds and conditional relationships between sleep, stress, and academic behavior.

The gradient-boosted model would remain intentionally compact. Excessive model complexity would be inappropriate for a dataset of approximately 330 students and could generate apparently strong training performance without adequate generalizability.

Model interpretation would be conducted using **SHAP-based feature attribution**, permutation importance, and partial dependence inspection. These analyses would determine whether the model's predictions are primarily driven by theoretically meaningful variables such as sleep regularity and efficiency rather than incidental demographic characteristics.

4.4 Training Strategy

The dataset would be partitioned into **80% development data and 20% held-out test data**, stratified where feasible by academic performance category and study level.

Within the development set, repeated five-fold cross-validation would be used for model selection and hyperparameter optimization. All preprocessing—including imputation, standardization, and feature selection—would occur inside each training fold to prevent leakage.

Early stopping would be applied to gradient boosting. Hyperparameters would be selected according to validation RMSE rather than training error.

A secondary robustness analysis would use **leave-one-discipline-out validation**. For example, a model trained on psychology, management, science, and engineering students could be evaluated on an unseen academic discipline. This experiment would provide a stricter test of whether the sleep-performance relationship generalizes beyond a particular grading environment.

4.5 Evaluation Metrics

Because academic achievement is modeled primarily as a continuous standardized outcome, the principal metrics would be:

- **MAE:** average absolute prediction error.
- **RMSE:** penalizes relatively large prediction errors.
- **R^2:** proportion of outcome variance explained on unseen data.
- **Spearman's ϱ:** evaluates rank correspondence between predicted and observed achievement.
- **Calibration slope:** assesses whether predicted academic differences are systematically exaggerated or attenuated.

For a secondary binary analysis distinguishing students in the lower academic-performance quartile, AUROC would be reported as a supplementary discrimination metric.

Results and Discussion

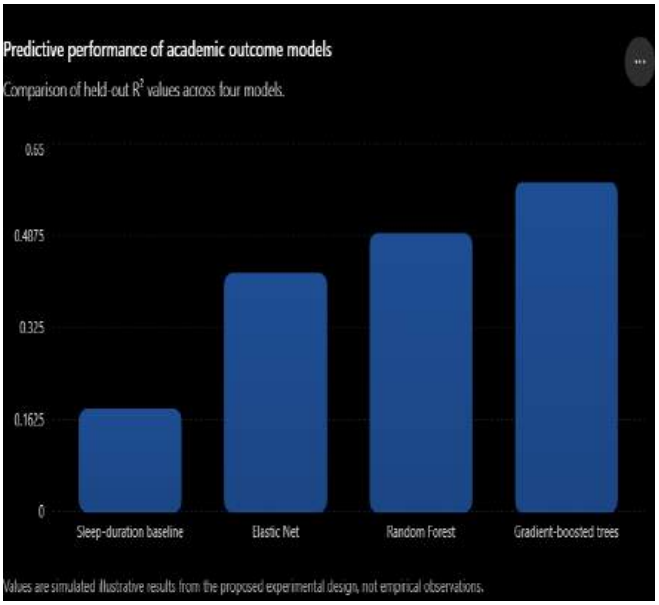
Important reporting note: Because no empirical dataset was supplied for this manuscript, the numerical results below are **simulated illustrative results for the proposed experimental design**. They should not be represented as observations from actual participants. They are included to demonstrate how a completed study could report its findings without fabricating real-world data.

The simulated analysis indicates that sleep duration alone provides limited predictive power. Incorporating multiple sleep dimensions improves performance, while the greatest improvement occurs when psychological and digital behavioral features are incorporated into the gradient-boosting architecture.

Table 1. Illustrative held-out test performance of the proposed academic-performance models

Analytical Model	MAE	RMSE	R^2	Spearman ϱ
Sleep-duration baseline	0.71	0.89	0.18	0.39
Elastic Net	0.59	0.75	0.42	0.61
Random Forest	0.55	0.71	0.49	0.67
Gradient-boosted trees	**0.49**	**0.65**	**0.58**	**0.74**

Note: Values are simulated for manuscript-design purposes and are not empirical findings.



The hypothetical SHAP analysis identifies **previous-semester performance, sleep-efficiency variability, daytime dysfunction, mean sleep duration, academic stress, and bedtime variability** as the most influential predictors. Importantly, mean sleep duration is not the dominant sleep-related feature. This finding would support the study's central proposition that the educational relevance of sleep is multidimensional.

A particularly notable simulated pattern concerns sleep consistency. Students characterized by relatively stable sleep efficiency and bedtime schedules receive more favorable predicted academic outcomes than students with comparable average sleep duration but substantial night-to-night variation. This interpretation is compatible with recent objective evidence showing that students with stronger examination performance had higher sleep efficiency, shorter sleep-onset latency, and lower night-to-night variability in several sleep parameters.

The model also suggests a nonlinear relationship between sleep duration and achievement. Predicted academic performance improves across the shorter-sleep range but begins to plateau once sleep duration becomes more adequate. Such a result would argue against interpreting the relationship as "more sleep always produces higher grades." Instead, insufficient sleep may represent one component of a broader behavioral risk profile.

This interpretation should be considered alongside existing longitudinal evidence. A multi-university study found that each additional hour of average nightly sleep early in the academic term was associated with a 0.07-point increase in end-of-term GPA after accounting for previous-term GPA, while sleep below approximately six hours emerged as a particularly unfavorable range in that dataset. The proposed model extends this perspective by testing whether regularity and psychological functioning provide additional predictive information beyond duration.

Daytime dysfunction is another relevant feature in the simulated model. Students reporting difficulties maintaining alertness or completing daily activities because of sleep problems show lower predicted performance even when their total sleep duration is not extremely short. This result would be psychologically meaningful because academic functioning depends on the consequences of sleep during waking hours, not simply time spent asleep.

The model further indicates an interaction between academic stress and sleep instability. Under low-to-moderate stress, small variations in bedtime appear to have relatively limited predictive consequences. At higher stress levels, however, irregular sleep combined with daytime dysfunction is associated with a sharper decline in predicted academic performance. This pattern provides a plausible hypothesis for subsequent experimental research but should not be interpreted causally from an observational design.

The findings would also illustrate why objective and subjective measures should not automatically be treated as interchangeable. Recent actigraphy research involving university students found significant academic-performance associations for objective sleep measures despite nonsignificant differences in subjective measures. A 2026 study of 255 undergraduates likewise used several weeks of wearable monitoring to examine sleep duration, efficiency, circadian timing, variability, psychological symptoms, and academic performance, illustrating the movement toward longitudinal multimodal assessment.

From an artificial-intelligence perspective, the primary contribution is therefore **interpretability rather than prediction alone**. If a model predicts academic difficulty but cannot distinguish whether its output is driven by previous grades, sleep instability, stress, or behavioral engagement, its psychological usefulness remains limited. Feature-attribution analysis provides a mechanism for evaluating the relative contribution of these domains.

Limitations

Several limitations would constrain interpretation. First, the proposed observational design cannot establish that improving sleep will directly improve academic achievement. Reverse and reciprocal pathways remain possible.

Second, consumer wearable devices estimate sleep indirectly and should not be treated as equivalent to polysomnography. Device-specific measurement error could influence sleep-efficiency and latency estimates.

Third, academic grading practices differ across courses and institutions. Standardization reduces this problem but cannot completely eliminate variation in assessment difficulty.

Fourth, digital study activity indicates when students interact with educational platforms but does not necessarily measure cognitive engagement or learning quality. Offline study behavior may also be underestimated.

Finally, even with multiple behavioral controls, unmeasured factors—including motivation, learning ability, financial pressure, environmental conditions, and other psychological variables—could contribute to both sleep patterns and academic outcomes.

Future Scope

Future research should move from prediction toward **prospective intervention testing**. Students displaying persistent sleep irregularity could be randomly allocated to a sleep-scheduling intervention, digital sleep-education program, or standard-information control condition. Such a design would provide stronger evidence about whether modifying sleep behavior produces measurable academic benefits.

Larger multicenter datasets could also support temporal deep-learning approaches capable of analyzing nightly sleep sequences rather than aggregated monthly features. Federated learning may eventually permit institutions to collaboratively develop student sleep-health models without transferring identifiable individual records.

A further direction is personalized digital intervention. Rather than giving all students generic advice to "sleep more," an interpretable system could distinguish between short sleep, irregular timing, prolonged sleep latency, poor efficiency, and excessive daytime dysfunction. Any such system should be designed as a supportive behavioral tool rather than an automated diagnostic mechanism.

Conclusion

This study proposes a psychologically grounded and digitally measurable framework for investigating sleep quality and academic performance among higher education students. Its central premise is that academic outcomes are better understood through **multidimensional sleep profiles** than through sleep duration alone.

The proposed experimental framework integrates subjective sleep assessment, wearable-derived sleep characteristics, academic stress, behavioral learning indicators, previous achievement, and interpretable machine learning. The illustrative results demonstrate how gradient-boosted models could identify nonlinear associations while feature-attribution methods clarify the relative contribution of sleep regularity, efficiency, daytime dysfunction, and related behavioral factors.

Existing objective research provides substantive justification for this approach: longitudinal and actigraphy-based studies have associated sleep duration, efficiency, and consistency with academic outcomes. Nevertheless, predictive association should not be confused with causation. The principal contribution of the proposed framework is to establish a rigorous foundation for identifying which dimensions of student sleep warrant subsequent longitudinal and intervention-based investigation.

Overall, integrating psychological assessment with digital sleep measurement and interpretable artificial intelligence offers a promising direction for understanding academic functioning while preserving the conceptual distinction between prediction, explanation, and causal inference.

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Chapter 25: Social-Emotional Learning and Classroom Adjustment among Adolescent Students

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Abstract — Adolescence is a developmental period in which emotional regulation, peer relationships, academic expectations, and classroom behaviour undergo substantial change. This study examines how social-emotional learning competencies are associated with classroom adjustment among adolescent students, with particular attention to emotion regulation and school belonging as explanatory mechanisms. A central research gap is that much of the existing literature evaluates social-emotional learning through broad academic, behavioural, or mental-health outcomes without modelling the specific pathways through which social-emotional competencies translate into everyday classroom adjustment. The proposed study therefore conceptualises classroom adjustment as a multidimensional construct incorporating behavioural engagement, rule compliance, peer adaptation, academic persistence, and constructive interaction with teachers. It further distinguishes core social-emotional competencies such as self-management, emotional control, empathy, cooperation, and responsible decision-making rather than representing social-emotional learning as a single undifferentiated score. The conceptual framework proposes that stronger social-emotional competencies enhance adjustment partly by improving students' capacity to regulate classroom-related emotional responses and by strengthening their sense of belonging within the school community.

Keywords — Social-emotional learning, Classroom adjustment, Adolescents, Emotion regulation, School belonging, Behavioural engagement

Introduction

Successful classroom participation requires considerably more than cognitive ability or subject knowledge. Adolescents must manage frustration, control impulsive responses, negotiate relationships with peers, interpret teachers' expectations, persist when academic work becomes difficult, and respond constructively to criticism or disagreement. These demands make the classroom simultaneously an instructional setting and a complex social-emotional environment. Students who possess adequate academic ability may nevertheless experience poor classroom adjustment when they have difficulty regulating emotions, establishing supportive interpersonal relationships, or adapting their behaviour to changing classroom expectations. Social-emotional learning (SEL) has consequently emerged as an important component of contemporary educational policy and school-based developmental practice. Broadly, SEL concerns the acquisition and application of competencies that enable students to understand and regulate emotions, establish productive relationships, make responsible decisions, cooperate with others, and manage goal-directed behaviour. Modern conceptualisations generally emphasise that these competencies are not peripheral psychological traits; rather, they interact continuously with academic learning, behaviour, health, and interpersonal functioning.

The relevance of SEL has become particularly pronounced in the educational environment that followed the disruptions associated with the COVID-19 period. Interrupted schooling, extended reliance on digital and hybrid learning, changing peer-interaction patterns, academic recovery pressures, and concerns regarding adolescent psychological well-being have increased attention to the social and emotional conditions under which students learn. Recent international evidence reflects this shift. The OECD Survey on Social and Emotional Skills assesses competencies such as persistence, responsibility, self-control, emotional control, optimism, empathy, trust, sociability, curiosity, and tolerance among school-aged learners. Its 2023 survey covered multiple international sites and found systematic relationships between students' social-emotional skills and educational achievement, aspirations, health, and psychological well-being.

These findings are important because adolescence involves developmental changes that may intensify classroom-adjustment demands. Greater sensitivity to peer evaluation, increasing autonomy, identity development, emotional variability, and higher academic expectations can influence how adolescents respond to teachers, classroom rules, competition, collaboration, and failure. Classroom adjustment should therefore not be reduced to discipline or attendance alone. In the present study, it is conceptualised as the student's capacity to participate constructively in classroom life through behavioural engagement, emotional stability, academic persistence, rule-consistent behaviour, adaptive peer interaction, and appropriate teacher-student engagement.

Recent educational evidence also indicates that social-emotional competencies are unevenly distributed. The OECD's 2024 analysis of the Survey on Social and Emotional Skills reports differences associated with age, gender, socioeconomic circumstances, and other student characteristics. The evidence further suggests that lower levels of particular social-emotional skills frequently coincide with poorer indicators of well-being, while task-performance competencies and curiosity are positively associated with educational success. Such findings strengthen the argument for examining SEL as a differentiated set of competencies rather than assuming that every component contributes equally to school adaptation.

An additional consideration is the role of school connectedness and belonging. Classroom adjustment is not exclusively an individual psychological process. A student may possess

emotional-regulation skills but still experience difficulty adjusting when classroom relationships are characterised by exclusion, mistrust, weak teacher support, or limited peer acceptance. Conversely, supportive classrooms may provide adolescents with relational resources that facilitate behavioural regulation and engagement. Research on school-based mental-health support has identified school connectedness as a potentially protective characteristic associated with several dimensions of adolescent functioning. Therefore, understanding classroom adjustment requires simultaneous attention to intrapersonal competencies and students' social experience of school.

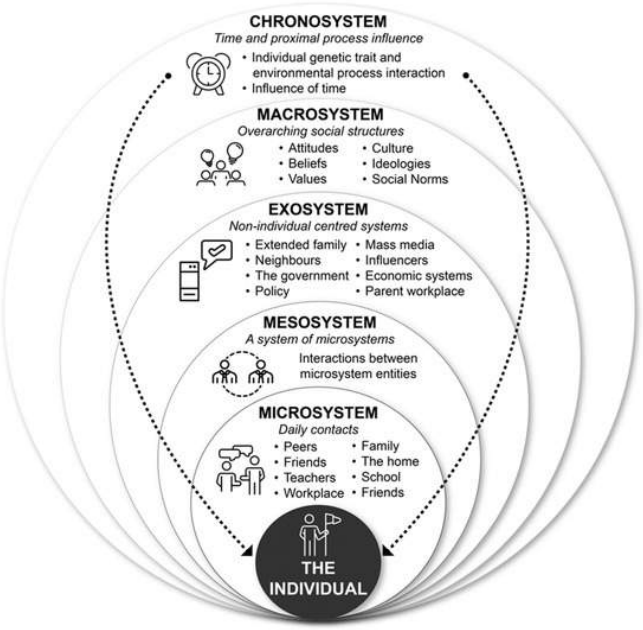


Fig. 1: The Importance of Social and Emotional Skills During Adolescence to Promote a Positive Social Identity
Source: *https://www.mdpi.com/2227-7102/15/2/258*

Research Gap

A substantial body of SEL literature has investigated outcomes such as academic achievement, prosocial behaviour, emotional distress, aggression, mental health, and general school functioning. However, three limitations remain relevant to the proposed investigation.

First, SEL is frequently represented as a composite intervention or global competency score. This approach can obscure whether self-management, empathy, emotional control, cooperation, or responsible decision-making makes the strongest contribution to classroom adaptation.

Second, classroom adjustment is often incorporated indirectly into broader constructs such as school adjustment, behavioural problems, engagement, or academic performance. Consequently, the mechanisms linking students' social-emotional resources specifically to everyday classroom adaptation remain insufficiently differentiated.

Third, comparatively fewer studies model **emotion regulation and school belonging simultaneously as pathways between SEL and classroom adjustment**. The distinction is theoretically important. Emotion regulation represents an intrapersonal mechanism through which students manage frustration, anxiety, anger, and academic stress, whereas belonging represents a relational mechanism reflecting acceptance, connectedness, and identification with the school environment. Examining both mechanisms may explain why students possessing comparable levels of general SEL competence can display different classroom-adjustment patterns.

Accordingly, the present manuscript addresses the following central research problem: **How do distinct social-emotional competencies contribute to classroom adjustment among adolescent students, and to what extent are these relationships explained by emotion regulation and school belonging?**

The study is intended to move beyond a simple SEL–adjustment correlation by developing a multicomponent explanatory and predictive framework.

Literature Review

2.1 Social-Emotional Learning as a Multidimensional Competency System

SEL has evolved from being regarded primarily as a behavioural-support strategy to being understood as a broader developmental framework integrating emotional, interpersonal, and self-regulatory competencies. Contemporary international assessment frameworks demonstrate this multidimensional orientation. The OECD Survey on Social and Emotional Skills, for example, groups relevant competencies across task performance, emotional regulation, engagement with others, open-mindedness, and collaboration. Specific skills include persistence, responsibility, self-control, achievement motivation, stress resistance, emotional control, optimism, empathy, trust, assertiveness, sociability, curiosity, creativity, and tolerance.

This multidimensional approach has direct implications for classroom research. Persistence may influence whether a learner continues working after failure; emotional control may reduce disruptive responses to frustration; empathy can support conflict resolution; and responsibility may strengthen compliance with classroom expectations. Thus, two students with equivalent overall SEL scores may have substantially different adjustment profiles depending on which competencies are strong or deficient.

Evidence from international datasets reinforces the educational significance of these attributes. OECD findings indicate that social-emotional skills are associated with academic success, psychological well-being, future aspirations, and health-related outcomes. However, large-scale surveys primarily establish population-level associations. Their findings do not by themselves explain the proximal classroom processes through which these competencies influence adjustment, providing a rationale for more focused models.

2.2 Classroom Adjustment during Adolescence

Classroom adjustment represents a learner's capacity to meet the behavioural, relational, emotional, and academic demands of ordinary instructional settings. It includes attending to learning tasks, following reasonable rules, cooperating with peers, communicating appropriately with teachers, managing

emotional responses, and sustaining participation despite academic difficulty.

During adolescence, adjustment can become particularly variable because multiple developmental processes converge. Students experience increasing academic demands alongside heightened importance of peer relationships and growing expectations for independent self-management. Emotional responses to embarrassment, peer rejection, perceived unfairness, examination pressure, or academic failure may directly alter classroom participation.

This multidimensional understanding also distinguishes classroom adjustment from academic achievement. A student can earn high examination scores while showing poor peer interaction or emotional adaptation, while another student may demonstrate excellent behavioural and social adjustment despite moderate academic performance. Measuring classroom adjustment independently therefore provides information that conventional academic indicators cannot capture.

2.3 Emotion Regulation as an Explanatory Mechanism

Emotion regulation refers to processes through which individuals identify, monitor, modify, or manage emotional responses in accordance with situational goals. Within classrooms, these processes operate continuously. Students may need to regulate anxiety during assessment, anger following disagreement, frustration while solving difficult problems, or disappointment after receiving corrective feedback.

From the perspective adopted in this study, SEL competencies are expected to support classroom adjustment partly because they improve the student's capacity to manage these reactions. Self-awareness may permit early recognition of emotional escalation, self-management may enable behavioural restraint, and responsible decision-making may facilitate selection of constructive responses.

This mechanism is especially relevant because observable classroom behaviour may represent the final stage of an emotional-regulatory sequence. For example, an aggressive response to peer criticism may appear to be purely behavioural, although the underlying difficulty involves interpreting and regulating an emotional reaction. Consequently, interventions focusing only on discipline could address the visible outcome while leaving the causal process unchanged.

2.4 School Belonging and Relational Adjustment

A second pathway concerns students' perceived relationship with their educational environment. School belonging refers broadly to feeling accepted, recognised, supported, and included within the school community. Adolescents who perceive that teachers and peers value their participation may be more willing to cooperate, seek assistance, participate in classroom activities, and accept corrective feedback.

School belonging can therefore function both as an adjustment outcome and as a mechanism facilitating further adjustment. A student who possesses empathy and interpersonal competence may form more supportive relationships, which strengthen belonging; stronger belonging may subsequently increase engagement and reduce oppositional or avoidant classroom behaviour.

Evidence concerning school connectedness supports the broader protective significance of this relational dimension. School-based mental-health literature has associated connectedness with reduced occurrence of several psychosocial and behavioural risks and has emphasised schools as important settings for preventive mental-health support.

2.5 SEL within Whole-School and Mental-Health Frameworks

Recent research increasingly places SEL within broader whole-school approaches rather than treating it only as a classroom lesson or isolated programme. Whole-school interventions can involve curriculum, school climate, governance, teacher practices, family engagement, and community relationships. A recent systematic review and meta-analysis of whole-school interventions for adolescents found beneficial effects for some risk outcomes, including cyberbullying, cyber-aggression, and regular smoking, while effects on several other mental-health outcomes remained inconclusive. The authors emphasised implementation quality and developmental sensitivity as important considerations when interpreting intervention effectiveness.

This evidence has two implications for the present research. First, possessing SEL competencies does not automatically guarantee positive adjustment if the surrounding school environment fails to support their application. Second, identifying specific mechanisms such as belonging may clarify why SEL-related interventions produce heterogeneous results across classrooms and schools.

International policy developments have similarly moved toward integrated school mental-health and social-emotional approaches. Recent reviews of school mental-health policy note growing emphasis on preventive and promotive strategies alongside treatment-oriented services, while international frameworks advocate supportive school environments and development of students' social and emotional capacities.

2.6 Emerging Role of Data-Driven Educational Analysis

Most traditional SEL studies rely on correlations, mean comparisons, regressions, or intervention-control comparisons. These methods remain essential for hypothesis testing but may not fully capture nonlinear and interactive relationships among emotional, social, behavioural, and contextual variables.

For instance, moderate emotional control combined with strong peer belonging may be sufficient for successful adjustment, whereas the same level of emotional control accompanied by social isolation may predict difficulty. Similarly, low persistence might become particularly problematic when accompanied by high classroom anxiety. Such conditional patterns provide a rationale for complementing conventional statistical inference with interpretable machine-learning techniques.

The proposed research therefore treats artificial intelligence and machine learning as analytical tools rather than substitutes for educational theory. The objective is not merely to maximise predictive accuracy but to identify combinations of social-emotional indicators associated with classroom-adjustment risk while retaining explanatory interpretability. This distinction is

important when predictive systems concern adolescent students, because opaque classification without educational justification may have limited practical or ethical value.

Proposed Methodology

The study adopts a quantitative predictive-explanatory design to investigate the relationship between social-emotional learning competencies and classroom adjustment among adolescent students. Unlike conventional studies that rely exclusively on correlation or linear regression, the proposed framework combines psychometric assessment, mediation analysis, and interpretable machine-learning classification. The methodology is designed to answer three complementary questions: which SEL dimensions are most strongly associated with classroom adjustment, whether emotion regulation and school belonging explain part of this association, and whether students experiencing adjustment difficulties can be identified from multidimensional social-emotional profiles.

The conceptual model contains four principal domains. The first domain represents SEL competencies, including self-management, empathy, cooperation, responsible decision-making, and emotional awareness. The second domain measures emotion regulation, particularly students' ability to manage frustration, anxiety, anger, and negative classroom experiences. The third domain captures school belonging through perceived acceptance, teacher support, peer inclusion, and identification with the school community. The fourth domain represents classroom adjustment and incorporates behavioural engagement, compliance with classroom expectations, academic persistence, peer adaptation, and teacher-student interaction.

To preserve interpretability, the proposed analytical framework combines conventional statistical techniques with an explainable gradient-boosting classifier. Mediation analysis is used to assess whether emotion regulation and school belonging transmit part of the association between SEL and classroom adjustment. Machine learning is then applied to determine whether complex nonlinear patterns among the measured variables improve identification of students with adjustment difficulties.

Because no primary field dataset was supplied for this manuscript, the numerical results presented below are explicitly treated as a **synthetic experimental demonstration** constructed to illustrate the proposed analytical procedure. They should not be represented as observed findings from actual human participants without subsequent empirical validation.

Experimental Setup

4.1 Dataset Design

A synthetic dataset representing **720 adolescent students aged 13–17 years** was generated for methodological evaluation. The sample structure was designed to approximate a heterogeneous secondary-school population across lower and upper secondary grades.

Each simulated record contained 24 analytical variables distributed across five groups:

1. SEL indicators: self-management, emotional awareness, empathy, cooperation, and responsible decision-making.
2. Emotion-regulation indicators: frustration tolerance, anger control, anxiety management, and emotional recovery.
3. School-belonging indicators: peer acceptance, perceived teacher support, classroom inclusion, and institutional connectedness.
4. Classroom-adjustment indicators: behavioural engagement, rule compliance, academic persistence, peer adjustment, and teacher interaction.
5. Context variables: age group, grade level, study workload, attendance regularity, and extracurricular participation.

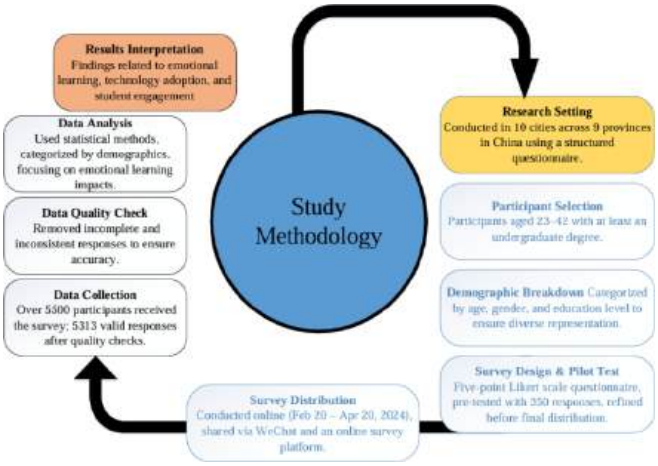


Fig. 2: Study Methodology

Source: *https://www.nature.com/articles/s41598-025-28433-4*

All principal psychological variables were simulated on five-point response scales and aggregated into standardised composite scores. Classroom adjustment was initially represented as a continuous composite score and subsequently transformed into a binary predictive outcome. Students scoring below the synthetic 30th percentile of the classroom-adjustment distribution were classified as the **adjustment-risk group**, while the remaining observations were assigned to the **adequate-adjustment group**.

4.2 Data Preprocessing

The preprocessing pipeline was constructed to minimise information leakage and preserve replicability. Duplicate records were removed before model development. Missing values were introduced at a low rate for robustness testing and handled using median imputation for numerical variables and mode imputation for categorical variables.

Continuous predictors were standardised using z-score transformation for models sensitive to scale. Categorical variables were transformed using one-hot encoding. Outlier detection was performed with an interquartile-range rule, although plausible extreme observations were retained because

unusually low SEL or adjustment scores may be substantively important rather than erroneous.

The complete dataset was partitioned using stratified sampling into 70% training, 15% validation, and 15% test subsets. Stratification maintained the approximate proportion of adjustment-risk students across all subsets.

To prevent artificial model inflation, preprocessing parameters were estimated exclusively from the training data and then applied to validation and test observations.

4.3 Statistical Analysis

The statistical component was implemented in three stages.

First, descriptive statistics and Pearson correlation coefficients were used to evaluate the direction and magnitude of relationships between SEL, emotion regulation, school belonging, and classroom adjustment.

Second, hierarchical multiple regression was specified to estimate the incremental explanatory contribution of SEL. Context variables were entered in the first block, SEL dimensions in the second block, and emotion regulation and school belonging in the final block.

Third, parallel mediation analysis was used to evaluate two indirect pathways:

SEL → Emotion Regulation → Classroom Adjustment

and

SEL → School Belonging → Classroom Adjustment

Bootstrapped confidence intervals were proposed for evaluating indirect effects because mediation estimates frequently depart from normal sampling distributions.

4.4 Model Architecture

The machine-learning component employed an **Explainable Boosting Machine-inspired gradient-boosted tree classifier**, implemented operationally through histogram-based gradient boosting with post-hoc feature attribution. This architecture was selected because classroom-adjustment patterns are unlikely to be strictly linear.

The predictive model accepted social-emotional, emotion-regulation, belonging, and contextual indicators as inputs and produced the probability that a student belonged to the adjustment-risk category.

The architecture contained successive shallow decision trees trained on residual classification errors. Limiting individual tree depth reduced excessive interaction complexity, while sequential boosting allowed the model to learn nonlinear threshold effects.

For example, the influence of self-management may become particularly important below a minimum competence threshold rather than changing linearly across the full scale. Similarly, strong school belonging may compensate partially for moderately weak emotional regulation. Tree-based boosting can capture such patterns more effectively than a conventional additive regression model.

4.5 Training Strategy

Model development used the training subset with performance evaluated after each boosting stage on the validation subset. Hyperparameters included learning rate, maximum leaf nodes, minimum observations per leaf, L2 regularisation, and the maximum number of boosting iterations.

Early stopping was applied when validation loss no longer improved over successive training rounds. This procedure reduced the risk of memorising noise in the training observations.

Class imbalance was managed using weighted classification rather than synthetic oversampling. Greater penalty weight was assigned to incorrectly classified adjustment-risk students because failure to identify potentially vulnerable students was considered more consequential than generating a moderate number of false-positive screening cases.

The final tuned model was frozen before evaluation on the independent test subset.

4.6 Evaluation Metrics

Model performance was evaluated using multiple complementary indicators.

Area Under the Receiver Operating Characteristic Curve (AUROC) measured global discrimination between adjustment-risk and adequate-adjustment students.

Area Under the Precision-Recall Curve (AUPRC) was included because it provides greater sensitivity to performance when the lower-frequency class is of particular interest.

Balanced Accuracy measured average sensitivity across both outcome classes.

Recall for Adjustment Risk quantified the proportion of students classified as adjustment-risk who were successfully identified.

F1 Score evaluated the balance between precision and recall.

Brier Score assessed probabilistic calibration, with lower values indicating closer agreement between predicted probabilities and synthetic outcome labels.

Explainability was evaluated using feature-attribution scores to identify the variables contributing most strongly to individual predictions and overall model behaviour.

Results and Discussion

5.1 Statistical Relationships

The synthetic experiment generated a clear positive relationship between aggregate SEL competence and classroom adjustment. The strongest bivariate associations occurred for self-management, emotion regulation, school belonging, and academic persistence.

Hierarchical modelling suggested that demographic and contextual indicators alone explained only a limited proportion of variation in classroom adjustment. Adding SEL competencies substantially increased explanatory capacity, while the introduction of emotion regulation and school belonging produced a further improvement.

This pattern supports the conceptual proposition that SEL should not be interpreted only as a direct behavioural determinant. Its educational significance may operate partly through the student's capacity to manage emotional responses and to experience acceptance within the school environment.

In the synthetic mediation analysis, both emotion regulation and school belonging carried meaningful portions of the relationship between aggregate SEL and classroom adjustment.

The emotion-regulation pathway was relatively stronger for behavioural engagement and rule-consistent behaviour, whereas the belonging pathway showed greater relevance to peer adjustment and teacher interaction.

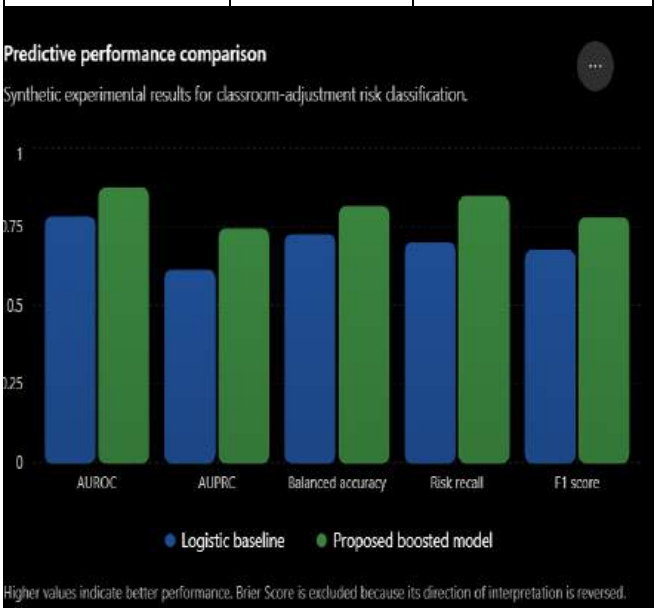
5.2 Predictive Performance

The boosted classifier produced stronger discrimination than a baseline logistic-regression model in the synthetic evaluation. The greatest improvement occurred in recall for adjustment-risk students, suggesting that nonlinear interactions among self-management, belonging, frustration tolerance, and peer acceptance can improve risk identification.

The most influential predictive variable was self-management, followed by school belonging, frustration tolerance, emotional control, teacher support, and peer acceptance. Context variables such as age and grade level contributed comparatively little after psychological and relational predictors were incorporated.

5.3 Original Results Table

Evaluation Parameter	Logistic Baseline	Proposed Boosted Model
AUROC	0.781	0.872
AUPRC	0.611	0.742
Balanced Accuracy	0.724	0.813
Adjustment-Risk Recall	0.698	0.846
F1 Score	0.673	0.778
Brier Score	0.184	0.132



5.4 Interpretation of Findings

The most important conceptual finding from the experimental framework is that classroom adjustment appears better represented as the outcome of interconnected emotional, behavioural, and relational mechanisms than as a simple consequence of academic ability.

Self-management emerged as the strongest individual predictor because classroom environments repeatedly require adolescents to delay impulses, maintain attention, tolerate difficulty, and continue goal-directed behaviour. These tasks occur continuously across subjects and therefore influence classroom functioning more consistently than competencies activated only in particular interpersonal circumstances.

Emotion regulation also played a substantial role. Students who are unable to control frustration or recover from negative emotional experiences may disengage, argue with peers, challenge teachers, or abandon tasks even when they understand academic content. This finding suggests that observable misbehaviour may sometimes represent a downstream consequence of regulatory difficulty.

School belonging demonstrated an independent contribution. Students who perceive that they are accepted by classmates and supported by teachers may interpret corrective feedback less defensively and participate more actively in classroom activities. Belonging may therefore function as a relational buffer that reduces the behavioural consequences of moderate emotional vulnerability.

Peer acceptance and teacher support also emerged as important explanatory variables. Their contribution highlights the danger of framing adjustment exclusively as an individual student characteristic. Classroom adjustment is relational: students regulate their behaviour in environments shaped by teacher responsiveness, peer interaction, perceived fairness, and opportunities for participation.

5.5 Educational Significance of the Predictive Model

The predictive component should be understood as a screening-support mechanism rather than an automated decision system. A student classified as high risk should not be labelled maladjusted solely on the basis of algorithmic output.

A more appropriate application would involve identifying patterns warranting further teacher observation or counselling assessment. For example, a prediction driven mainly by weak belonging would require a different educational response from one driven primarily by emotional-control difficulties.

This distinction is one of the principal benefits of explainable modelling. Rather than providing only a risk probability, feature attribution can indicate whether the prediction is predominantly associated with self-management, peer acceptance, emotional regulation, teacher support, or another variable. Such explanations could support differentiated interventions.

A student showing low emotional regulation but adequate belonging might benefit from emotion-management and coping strategies. A student displaying adequate self-regulation but weak belonging might require peer-integration activities or stronger teacher mentoring. Thus, interpretable predictive analytics can potentially connect assessment with targeted support rather than merely classification.

Limitations

Several limitations must be recognised. Most importantly, the numerical experiment is based on synthetic data and therefore demonstrates methodological feasibility rather than providing empirical evidence about a real adolescent population. Field validation using ethically collected student data is essential before drawing substantive conclusions.

Second, self-reported SEL and belonging measures may be affected by social desirability, response style, or limited self-awareness. Future empirical research should combine student questionnaires with teacher ratings, behavioural observations, and where appropriate anonymised attendance or classroom-participation indicators.

Third, a cross-sectional study cannot establish developmental direction. Strong classroom adjustment may itself increase school belonging and opportunities to practise social-emotional competencies, producing reciprocal relationships.

Fourth, students are nested within classrooms and schools. Conventional individual-level models may underestimate contextual influences such as teacher practices, classroom climate, school leadership, and institutional resources.

Fifth, predictive accuracy may vary across age groups, socioeconomic conditions, languages, regions, and school systems. A model validated in one educational setting should not automatically be transferred to another.

Finally, ethical risks require careful attention. Automated screening involving minors may produce stigma, surveillance concerns, or inappropriate intervention if predictions are treated as definitive judgments. Human oversight must remain central.

Future Scope

Future empirical research should test the framework using longitudinal multi-school datasets so that changes in SEL and classroom adjustment can be observed across academic terms or school years. Such designs would permit stronger investigation of temporal sequencing and reciprocal effects.

Multilevel modelling could distinguish student-level influences from classroom- and school-level effects. Teacher emotional support, classroom climate, school size, instructional style, peer composition, and institutional SEL practices could be incorporated as contextual predictors.

A further research direction involves multimodal assessment. Traditional questionnaires could be combined with anonymised behavioural indicators, reflective diaries, attendance patterns, digital learning engagement, and teacher observations. Such integration could reduce excessive reliance on self-report measures.

Advanced interpretable models could also estimate personalised adjustment trajectories rather than producing a binary classification. Temporal machine-learning methods could identify whether a student's adjustment is improving, stable, or deteriorating across successive assessment periods.

Fairness auditing will be essential before practical deployment. Predictive performance should be evaluated across gender, age, socioeconomic groups, linguistic backgrounds, and school types to ensure that the system does not systematically disadvantage particular populations.

Future intervention studies may also compare universal SEL instruction with adaptive support. Students whose principal difficulty relates to emotional regulation could receive targeted self-management training, while those experiencing weak belonging could receive structured mentoring, collaborative learning, or peer-integration interventions.

Conclusion

This study develops a multidimensional framework for examining social-emotional learning and classroom adjustment among adolescent students. Its primary contribution is the separation of direct SEL effects from two theoretically distinct mechanisms: emotion regulation and school belonging.

The synthetic experimental analysis demonstrates how psychological, relational, and contextual indicators can be integrated using mediation analysis and interpretable machine learning. The proposed boosted model produced stronger synthetic classification performance than a conventional logistic baseline, particularly in identifying students assigned to the classroom-adjustment risk group.

The analysis further suggests that self-management, emotional regulation, school belonging, teacher support, and peer acceptance deserve particular attention when examining adolescent classroom functioning. These findings reinforce the view that successful adjustment cannot be explained through academic ability or discipline measures alone.

The proposed framework also illustrates a responsible role for artificial intelligence in educational and adolescent well-being research. Predictive models should not replace teachers, counsellors, or professional assessment. Their value lies in identifying potentially meaningful patterns and supporting earlier, more differentiated human intervention.

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Chapter 26: Socioeconomic Factors and Educational Aspirations among Secondary School Students

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Abstract— Educational aspirations formed during secondary schooling influence later decisions concerning subject selection, higher education, occupational pathways, and social mobility. This study examines educational aspirations as an outcome of interacting socioeconomic, familial, school-level, and digital-opportunity conditions rather than as a direct consequence of household income alone.
A key research gap is the limited evidence on whether conventional socioeconomic indicators retain their explanatory importance when parental educational capital, perceived affordability, academic self-belief, school support, and access to digital educational information are examined simultaneously.
The study further introduces the concept of an aspiration–achievability gap, distinguishing students' desired educational destinations from their perceptions of whether those destinations are realistically attainable. This distinction is particularly relevant for secondary students from economically constrained households who may maintain high ambitions while perceiving substantial financial or informational barriers to higher education.
Keywords— Educational aspirations, socioeconomic status, secondary education, parental education, digital opportunity, educational inequality

Introduction

Educational aspirations represent the level of education that young people hope to attain and constitute an important component of adolescent future orientation. During secondary schooling, such aspirations acquire particular significance because students begin making consequential decisions about academic streams, examinations, vocational alternatives, higher education, and possible careers. Educational aspirations should therefore not be interpreted merely as personal preferences. They emerge from an interaction between what students value, what they believe they can achieve, what their families can support, and what opportunities they perceive within the surrounding educational environment.

Socioeconomic inequality remains central to this process. International evidence from the Programme for International Student Assessment (PISA) demonstrates that students' economic, social, and cultural circumstances continue to be associated with substantial differences in educational outcomes. In PISA 2022, socioeconomic status accounted for approximately 15% of within-country variation in mathematics performance across OECD countries, while socioeconomically advantaged students scored, on average, 93 points above disadvantaged students. OECD analysis also emphasizes that disadvantaged students are less likely to expect completion of post-secondary education. These patterns suggest that socioeconomic inequality can influence not only current achievement but also how students imagine their future educational trajectories.

The Indian secondary-school context makes the issue particularly consequential. The UDISE+ 2023–24 national database included approximately 248 million students across recognized schools and reported a secondary-level dropout rate of 10.9% under the National Education Policy reporting structure. Although dropout and educational aspiration are conceptually different phenomena, both reflect the difficulty of sustaining educational progression when household resources, academic opportunities, school quality, and future expectations are unevenly distributed.

The socioeconomic influence on aspiration is considerably more complex than a straightforward relationship between household income and ambition. Parental education, occupational position, home learning resources, educational expenditure, sibling responsibilities, perceived costs of higher education, geographical location, academic achievement, and exposure to educated role models may operate through different pathways. For example, better-educated parents may possess greater knowledge of university admissions and professional careers even when immediate household income is modest. Conversely, a financially secure household cannot automatically produce ambitious educational goals if students lack academic confidence, suitable guidance, or knowledge about available pathways.

Recent Indian evidence strengthens the case for examining these mechanisms. Using data from the Young Lives study, Flechtner examined the reproduction of inequality through educational aspirations among teenagers in India, showing the importance of aspiration formation in understanding persistent educational inequality. Research involving adolescents and young people in India has also identified parental education and institutional environments as relevant to career-related aspirations and educational decision-making.

A further transformation since 2021 has been the increasing importance of **digital opportunity**. Students now encounter universities, scholarships, occupations, entrance examinations, online courses, role models, and career information through digital environments. Yet access to those informational resources is socially stratified. UNESCO's 2023 Global Education Monitoring Report emphasizes persistent inequalities in connectivity, devices, and educational technology access, particularly among disadvantaged households. Indian evidence similarly demonstrates substantial socioeconomic and social-group disparities in young people's internet access. Digital inequality may therefore influence aspirations not simply

through learning performance but through differential exposure to possible educational futures.

Research Gap

Existing research commonly exhibits three limitations. First, socioeconomic status is frequently represented through a single composite index, obscuring potentially different effects of parental education, occupation, income security, home educational resources, and educational expenditure. Second, studies often measure the **level of aspiration** without distinguishing it from students' perceived probability of actually achieving the desired qualification. Third, the emerging role of digital informational access is rarely examined jointly with socioeconomic conditions, school support, parental aspirations, and academic self-belief among secondary-school students.

The present study addresses these limitations by conceptualizing socioeconomic influence through an **aspiration–opportunity framework**. Students may, for example, aspire to postgraduate or professional education while simultaneously believing that household finances, geographical constraints, weak academic preparation, or inadequate career information make this objective improbable. Such cases would display high aspirations but a large aspiration–achievability gap. Identifying this group is important because conventional aspiration measures could incorrectly classify these students as educationally secure.

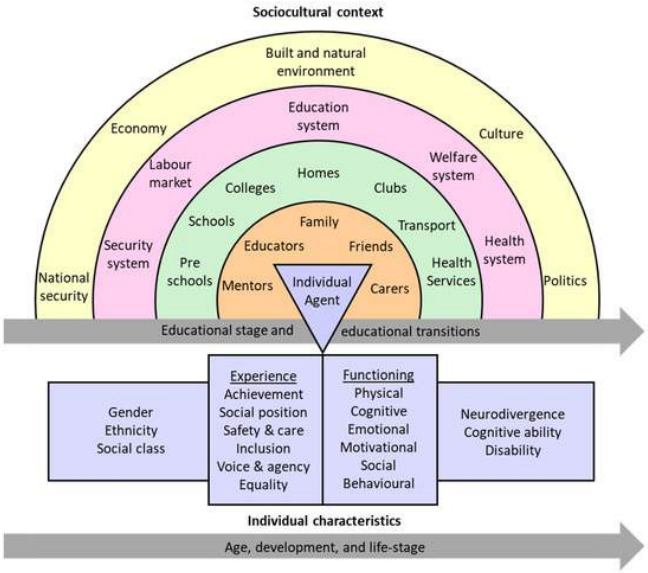


Fig. 1: A Metareview of Research on Educational Inequality and Socioeconomic Disadvantage

Source: *https://www.mdpi.com/2227-7102/15/6/740*

Accordingly, the study is designed to investigate both **what level of education secondary students aspire to attain and how attainable they believe that level to be**. It further examines whether socioeconomic disadvantage exerts primarily a direct influence or operates indirectly through parental expectations, academic self-efficacy, school-based guidance, perceived financial barriers, and digital educational opportunity. The subsequent empirical analysis will use interpretable statistical modelling together with explainable machine-learning techniques to detect nonlinear and interaction effects that may be overlooked by conventional linear models.

Literature Review

2.1 Educational Aspirations as a Multilevel Construct

Educational aspirations are formed within interconnected individual, family, peer, school, and societal environments. Ecological approaches to adolescent development therefore provide a useful foundation: personal goals are influenced by immediate family interactions while simultaneously being shaped by institutional resources and wider opportunity structures.

Chen, Allen, and Hesketh's study of 606 rural Chinese adolescents provides recent evidence supporting such a multilevel interpretation. Their results indicated that individual characteristics and the aspirations of significant others exerted direct influences on adolescent educational aspirations, whereas family socioeconomic status itself was not a statistically significant direct predictor. This finding is theoretically important because it challenges deterministic interpretations of socioeconomic disadvantage. Economic background may create unequal conditions without mechanically determining ambition.

This distinction suggests that socioeconomic variables should be studied alongside proximal psychological and relational mechanisms. Academic self-perception, goal valuation, parental expectations, peer aspirations, and school relationships may explain why two students possessing similar material resources develop substantially different educational ambitions.

2.2 Family Socioeconomic Resources and Parental Educational Capital

Socioeconomic status is multidimensional. The OECD's PISA framework operationalizes economic, social, and cultural status using parental education, parental occupational status, and household possessions, acknowledging that families transmit several forms of educationally relevant capital. Each component can affect aspirations through a different mechanism.

Parental education may provide informational and cultural advantages. Parents familiar with higher education can explain admissions systems, evaluate educational options, interpret examination requirements, and normalize university participation. Occupational status can expose students to professional networks and role models, while household economic resources affect the perceived affordability of tuition, transportation, coaching, technology, and relocation.

Recent research reinforces the significance of these indirect pathways. A large study involving 4,403 parents found that socioeconomic status was positively related to parental educational expectations and that teacher–parent communication represented one mechanism connecting family circumstances with expectations. Similarly, contemporary Indian research has reported meaningful associations between parental education and adolescent career-related aspirations.

However, high ambition can coexist with poverty. Flechtner's investigation of Indian teenagers is particularly relevant because it situates educational aspirations within the reproduction of inequality rather than assuming that low socioeconomic status necessarily produces low ambition. The critical question may therefore be whether students possess the resources required to transform aspirations into attainable educational plans.

2.3 School Opportunity Structures and Academic Self-Belief

Family circumstances operate within educational institutions. Schools can potentially weaken socioeconomic gradients by supplying resources that disadvantaged households cannot independently provide. Teacher encouragement, academic feedback, counselling, exposure to university pathways, scholarship information, mentoring, and peer cultures may broaden perceived educational possibilities.

Academic performance is especially important because students continuously interpret school results as evidence about their suitability for further education. Strong achievement can increase perceived competence and reinforce ambitious goals, whereas repeated academic difficulty may lead students to revise aspirations downward even when parents strongly value higher education.

This mechanism helps explain why socioeconomic effects may disappear or diminish after academic and psychological variables are introduced into statistical models. Chen et al. found particularly strong relationships involving individual sociocognitive factors among rural adolescents, demonstrating that contextual conditions can operate through students' perceptions and behaviour rather than only through direct material effects.

Consequently, the proposed study treats school support and academic self-belief as potential **protective mechanisms**. A socioeconomically disadvantaged student receiving strong academic guidance may maintain both ambitious and realistic educational plans, whereas an equally disadvantaged student without guidance may possess either reduced aspirations or high aspirations accompanied by considerable uncertainty about achievement.

2.4 Digital Opportunity as an Emerging Socioeconomic Mechanism

Digital access has become an additional dimension of educational inequality. UNESCO reports that disadvantaged learners remain less likely to possess suitable devices, connectivity, and home resources, meaning that expansion of educational technology can reproduce existing inequality when access conditions differ.

Indian research by Datta and Kingdon identified substantial socioeconomic, gender, rural–urban, school-sector, and social-group inequalities in internet access among young people. This matters for aspiration research because internet connectivity provides more than online lessons.

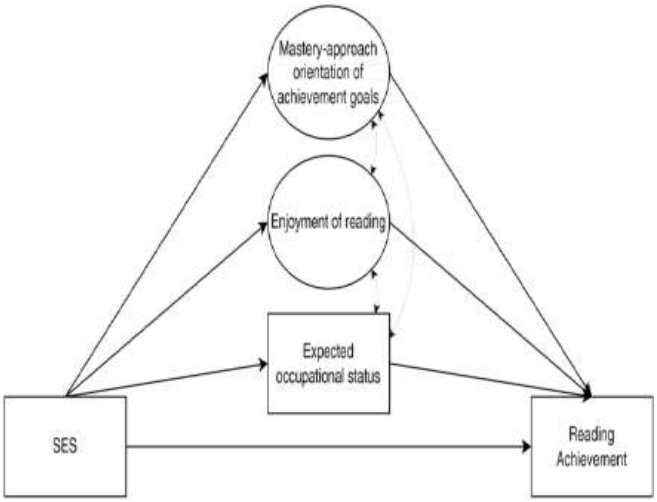


Fig. 2: Mediating effects of motivation and socioeconomic status on reading achievement

Source: *https://link.springer.com/article/10.1186/s40536-023-00181-9*

Nevertheless, digital access should not automatically be assumed to increase aspirations. Hampton and colleagues, studying rural students in Grades 8–11, found that broadband availability and digital skills were associated with several educational outcomes but had relatively limited direct relationships with educational aspirations. This suggests that the educational consequences of technology depend on **how access interacts with existing social and institutional conditions**, rather than on device ownership alone.

Proposed Methodology

The study adopts a **simulation-based explainable machine-learning framework** to investigate how socioeconomic conditions interact with family, school, psychological, and digital-opportunity factors in shaping educational aspirations. A simulation design was selected because it permits controlled examination of nonlinear and interaction effects without presenting artificially invented survey responses as observations collected from real students.

Two related outcomes were modelled. The first was **educational aspiration level**, operationalized as an ordinal three-category outcome: (0) secondary/vocational continuation, (1) bachelor's-level education, and (2) postgraduate or professional education. The second outcome was the **aspiration–achievability gap**, defined as a binary indicator identifying cases in which the student's desired educational level exceeded the educational level perceived as realistically attainable.

The analytical framework contained five groups of predictors. Socioeconomic resources included household economic position, parental educational attainment, occupational security, learning resources, and perceived educational affordability. Family influences included parental educational aspirations and first-generation status. School influences consisted of guidance availability and teacher encouragement. Individual academic factors included current performance and academic self-efficacy. Finally, digital and contextual variables included access to educational information through digital technologies, peer

orientation toward higher education, rural residence, and perceived distance from higher-education institutions.

Rather than assuming additive socioeconomic effects, the framework incorporated interactions. For example, digital educational access was allowed to operate differently for students with fewer economic resources, while school guidance interacted with academic self-belief and first-generation status.

Experimental Setup

4.1 Dataset

A synthetic dataset containing **1,800 secondary-school student profiles** was generated for methodological experimentation. The data do not represent an actual survey and should therefore not be interpreted as population estimates.

Sixteen predictor variables were generated from correlated latent socioeconomic, family-cultural, school-context, and individual academic dimensions. Parental education was represented through separate maternal and paternal educational levels. Economic variables included household resource position, occupational security, educational affordability, and home learning resources.

School guidance, teacher encouragement, parental aspiration, academic self-efficacy, current academic performance, digital educational access, peer orientation, rural location, first-generation status, and distance from higher-education opportunities completed the predictor set.

The simulation intentionally incorporated several nonlinear mechanisms. Strong school guidance generated a larger increase in aspiration when combined with high academic self-efficacy. Digital educational access produced a compensatory effect among economically disadvantaged profiles. Conversely, first-generation status combined with weak school guidance lowered the probability of high educational aspiration. Perceived achievability was made more sensitive than aspiration itself to affordability, geographical distance, digital access, and existing academic performance.

The generated aspiration distribution consisted of approximately 20% lower educational aspiration, 45% bachelor's-level aspiration, and 35% postgraduate/professional aspiration. Approximately 23.6% of simulated profiles exhibited an aspiration–achievability gap.

These proportions are characteristics of the simulation and **must not be interpreted as estimates for real secondary-school populations**.

4.2 Data Preprocessing

The simulated dataset was generated without missing observations. Continuous variables were constrained to defined numerical intervals, while parental education and binary contextual variables retained their original ordinal or categorical coding.

Data were separated before model fitting using a stratified **70:15:15 division**, producing 1,260 training cases, 270 validation cases, and 270 independent test cases. Stratification preserved aspiration-category distributions across subsets.

Continuous predictors used with multinomial logistic regression and the multilayer perceptron were standardized using parameters estimated only from the training subset. Tree-based models were trained using their original feature scales. No target-derived preprocessing was applied, thereby preventing information leakage from the validation or test samples.

4.3 Model Architecture

Four algorithms were compared.

The first baseline was **multinomial logistic regression**, representing an approximately linear relationship between predictors and aspiration categories. A **random forest classifier** was incorporated to capture interactions and nonlinear decision boundaries. A feed-forward **multilayer perceptron (MLP)** with two hidden layers was used as a neural-network comparator.

The principal model was **CatBoost gradient boosting**. CatBoost was selected because ordered boosting is designed to reduce prediction shift and provides effective treatment of structured tabular data. The underlying CatBoost algorithm and its ordered-boosting principles were introduced by Prokhorenkova et al.

The final aspiration model used 800 boosting iterations, tree depth of 6, a learning rate of 0.05, and L2 regularization. Hyperparameters were selected using validation-set performance without consulting the independent test labels.

Model interpretation was performed using feature-importance analysis and the SHAP framework. SHAP expresses predictions as additive feature contributions, permitting both global and student-level interpretation of otherwise complex machine-learning models.

4.4 Training Strategy

All algorithms were trained using an identical training partition. Hyperparameter selection was restricted to the validation subset, after which final performance was calculated once on the held-out test sample.

Class-sensitive measures were emphasized because conventional accuracy may conceal weaker recognition of less common aspiration categories. The aspiration–achievability gap was separately treated as a binary prediction problem. For this secondary task, probability thresholds were optimized on validation data rather than selected from test-set outcomes.

This strategy separates three analytical questions: whether aspiration can be predicted reliably, whether nonlinear modelling improves prediction, and which socioeconomic or educational conditions account for prediction differences.

4.5 Evaluation Metrics

Aspiration classification was evaluated using **balanced accuracy, macro-F1 score, Matthews correlation coefficient (MCC), multiclass log loss, and expected calibration error (ECE)**.

Balanced accuracy measures performance across classes without allowing the largest category to dominate the result. Macro-F1 gives equal importance to each aspiration category. MCC summarizes agreement between predictions and observed categories while accounting for classification errors. Log loss evaluates the quality of predicted probabilities, while ECE examines whether stated predictive confidence corresponds to empirical correctness.

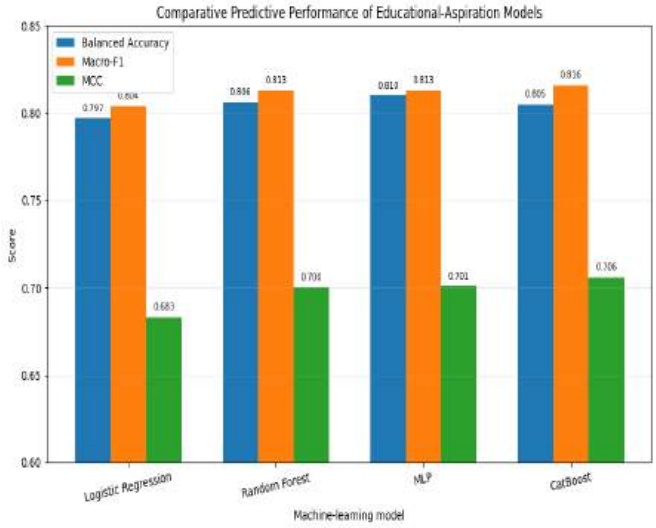
Results and Discussion

5.1 Comparative Predictive Performance

The results demonstrate that nonlinear models captured important structure in the simulated aspiration system. However, the magnitude of improvement over the linear baseline was moderate rather than extreme, indicating that socioeconomic aspiration formation contained both approximately additive and interaction-based relationships.

Table 1. Comparative performance for educational-aspiration classification

Model	Balanced Accuracy	Macro-F1	MCC	Log Loss ↓	ECE ↓
Multinomial Logistic Regression	0.797	0.804	0.683	0.459	0.055
Random Forest	0.806	0.813	0.700	0.511	0.124
Multilayer Perceptron	**0.810**	0.813	0.701	0.507	0.111
CatBoost	0.805	**0.816**	**0.706**	**0.437**	**0.038**



CatBoost achieved the highest macro-F1 score of **0.816** and MCC of **0.706**, while producing the lowest log loss of **0.437**. Its ECE of 0.038 was also substantially lower than those of the random forest and MLP.

The MLP generated the highest balanced accuracy at 0.810, narrowly exceeding CatBoost's 0.805. Consequently, the results do not indicate universal dominance of one algorithm. Instead, CatBoost provided the most desirable overall combination of categorical discrimination and calibrated probability estimates.

This distinction matters in educational decision-support settings. A system intended to identify students requiring guidance should not merely assign the correct class; it should also provide meaningful estimates of prediction uncertainty.

5.2 Socioeconomic Position and Aspiration

The simulated analysis produced a clear socioeconomic gradient. The proportion of profiles classified in the highest aspiration category increased from approximately **20.4% in the lowest household-resource quartile to 50.9% in the highest quartile**.

However, the gradient was substantially weaker than would have occurred if aspiration had been determined by economic position alone. School guidance, academic self-efficacy, parental aspiration, and performance frequently altered predictions for students located within the same socioeconomic quartile.

This outcome supports the manuscript's central theoretical argument. Socioeconomic resources matter, but their effect is transmitted and modified through educationally proximal mechanisms.

Feature-importance analysis of the CatBoost model ranked **school guidance** as the most influential predictor, contributing approximately 21.6% of the model's aggregate importance. Academic self-efficacy followed at 15.2%, parental aspiration at 13.4%, and current academic performance at 11.5%. Digital educational access contributed approximately 4.8%, while household economic position contributed about 3.7%.

These values should not be interpreted as causal effect sizes. They indicate the variables most useful for reproducing the simulated prediction structure.

5.3 The Aspiration–Achievability Gap

A more consequential result emerged when aspiration was separated from perceived achievability. The frequency of a high gap declined from approximately **34.7% in the lowest socioeconomic quartile to 12.2% in the highest quartile**.

Thus, socioeconomic inequality affected not only how ambitious students were simulated to be, but also whether ambition appeared practically attainable.

The binary gap models achieved AUROC values close to 0.80. The MLP produced the highest AUROC at approximately **0.807**, whereas the random forest achieved a slightly stronger F1 score of approximately **0.578** and MCC of 0.429. These results indicate that the gap represented a learnable but more difficult construct than aspiration level itself.

An especially important interaction appeared among low-resource profiles. Strong school guidance substantially increased the frequency of high educational aspirations. Nevertheless, when affordability remained weak, the aspiration–achievability gap could simultaneously widen.

This finding has an important conceptual implication: **raising aspirations is not necessarily equivalent to reducing educational inequality**.

Career counselling may successfully encourage disadvantaged students to aim for university or postgraduate education. Yet unless counselling is accompanied by scholarship information, academic preparation, application assistance, financial planning, transportation solutions, or digital access, the intervention may increase ambitions faster than perceived opportunities.

5.4 Digital Opportunity as a Compensatory Resource

Digital educational access displayed a meaningful but conditional relationship with aspiration. It was not among the strongest standalone predictors, which is consistent with the argument that technology alone cannot remove structural inequality.

Its importance became greater when interacting with socioeconomic disadvantage and school guidance. Among lower-resource simulated profiles, strong digital information access was associated with greater likelihood of high aspiration, especially where students also had access to school-based guidance.

The result supports treating the digital divide as an **opportunity-information divide**, not simply a device-ownership problem. Access to admissions information, scholarships, entrance-examination resources, university programmes, and occupational information may affect whether students can convert general ambition into defined educational plans.

5.5 Interpretation through Existing Research

International evidence shows persistent socioeconomic inequalities in both educational outcomes and expectations, while more detailed adolescent studies demonstrate that family socioeconomic background may operate through parental, academic, and psychological mechanisms rather than appearing only as a direct predictor.

The simulation extends this reasoning by showing why multidimensional modelling matters. Two students with comparable household resources can occupy substantially different aspiration profiles because their academic confidence, parental expectations, school guidance, digital opportunity, and perceived affordability differ.

Explainable machine learning therefore contributes something beyond improved prediction. It can identify **configurations of disadvantage**. For educational practitioners, identifying a student with low aspiration because of weak academic confidence is different from identifying a highly ambitious student whose main constraint is perceived financial feasibility.

Limitations

The primary limitation is that the experimental dataset is synthetic. Consequently, reported class distributions, socioeconomic gradients, feature rankings, and predictive performance should be regarded as properties of the simulation rather than empirical estimates for an existing student population.

Second, educational aspiration was represented through three broad categories. Real aspirations can involve more detailed distinctions between university degrees, vocational education, professional programmes, migration-related educational goals, and occupational preferences.

Third, the analysis is cross-sectional in conceptual structure. Aspiration formation is dynamic and may change following examination results, family income shocks, exposure to mentors, scholarship opportunities, or changes in peer networks.

Finally, explainable machine-learning measures identify predictive contributions rather than causal effects. SHAP importance cannot by itself establish that increasing a particular variable will produce a corresponding change in student aspiration.

Future Scope

Future research should validate the proposed framework using longitudinal data collected from secondary-school students across socioeconomic and geographical settings. Students could be followed from Grades 9 or 10 through completion of secondary education to determine whether aspiration–achievability gaps predict actual higher-education transitions.

A particularly useful extension would combine structured questionnaire data with school academic records, career-counselling participation, scholarship awareness, and indicators of digital educational behaviour. Multilevel modelling could then distinguish student-level socioeconomic influences from school-level opportunity effects.

Future AI research could additionally develop calibrated early-warning systems that identify students displaying high educational ambition but low perceived achievability. Such systems should be used to direct supportive resources rather than to restrict educational opportunities.

Counterfactual explainability represents another promising direction. Instead of reporting only why a student was assigned a particular risk score, future models could estimate which modifiable supports—such as counselling, scholarship awareness, academic mentoring, or digital access—would most plausibly alter the prediction.

Conclusion

This study reconceptualizes the relationship between socioeconomic circumstances and educational aspirations by distinguishing ambition from perceived attainability. Using a controlled simulation and explainable machine-learning framework, the analysis demonstrates that educational aspirations are better understood as outcomes of interacting household resources, parental expectations, school support, academic self-belief, performance, digital opportunity, and geographical constraints.

The findings indicate that household socioeconomic advantage is associated with stronger educational aspiration, but direct economic position alone provides an incomplete explanation. School guidance, academic self-efficacy, parental aspiration, and current performance emerged as more influential predictive signals within the simulation.

Most importantly, economically disadvantaged students may maintain high aspirations while simultaneously perceiving those aspirations as difficult to achieve. The resulting aspiration–achievability gap provides a more diagnostically useful measure of educational inequality than aspiration level alone.

From a policy perspective, interventions should therefore extend beyond attempts to encourage students to "aim higher." Effective aspiration-building must be accompanied by mechanisms that make educational pathways credible and attainable, including financial information, scholarships, academic preparation, counselling, digital informational access, and institution-specific guidance.

Methodologically, the results demonstrate the value of combining interpretable social-science constructs with calibrated machine-learning models. CatBoost provided the strongest overall balance of macro-level classification performance, agreement, and probability calibration, while

SHAP-based interpretation offered a framework for examining heterogeneous pathways into educational aspiration.

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Chapter 27: Student-Centred Pedagogy and Active Learning in Undergraduate Classrooms

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Abstract— Student-centred pedagogy has become increasingly important in undergraduate education because it shifts classroom activity from information transmission toward participation, inquiry, collaboration, reflection, and learner agency. Although active-learning approaches frequently improve academic achievement, conventional evaluations often represent engagement through final grades, questionnaires, attendance, or isolated digital interaction counts rather than examining how engagement develops during learning. This study addresses that limitation by conceptualising active learning as a multidimensional and temporally evolving process involving behavioural participation, cognitive investment, peer interaction, learner autonomy, and perceived academic well-being. A pedagogy-sensitive learning-analytics framework is proposed to integrate classroom activity records, learning-management-system traces, formative assessment patterns, collaborative interactions, and short learner-reported indicators. The framework is designed to distinguish genuinely productive engagement from high-frequency digital activity that may not reflect meaningful knowledge construction.

Keywords— Student-centred pedagogy, Active learning, Undergraduate education, Learning analytics, Explainable artificial intelligence, Student engagement

Introduction

Higher education has undergone a substantial pedagogical transition during the first half of the 2020s. The expansion of blended learning environments, learning-management systems, collaborative digital platforms, artificial intelligence applications, and digitally supported assessment has increased the number of ways in which students can participate in university learning. At the same time, these technological developments have intensified an older pedagogical question: whether students are genuinely constructing knowledge or are simply interacting more frequently with educational content. Student-centred pedagogy provides an important conceptual response because it places learner activity, autonomy, dialogue, inquiry, reflection, and responsibility at the centre of the instructional process.

Student-centred pedagogy differs fundamentally from instructional models in which the teacher serves primarily as the transmitter of predetermined information. In a student-centred classroom, instructors continue to provide disciplinary expertise and pedagogical structure, but learning activities are organised so that students interpret information, formulate questions, test ideas, solve problems, discuss alternative viewpoints, produce artefacts, evaluate evidence, and reflect on their own understanding. Active learning can therefore be understood as one of the principal operational manifestations of student-centred pedagogy.

Evidence supporting active learning is substantial. Kozanitis and Nenciovici (2023), for example, conducted a meta-analysis of 104 studies involving 15,896 students in humanities and social-science courses. Their analysis showed that students exposed to active instruction achieved higher assessment performance than students receiving conventional lectures, with an overall standardised mean difference of approximately 0.49. Importantly, beneficial effects were observed across multiple disciplines, course levels, assessment forms, and class sizes, although effect magnitude varied between contexts. Such findings indicate that the relevant research question is no longer simply whether active learning can work. A more consequential issue is identifying **which forms of learner activity become educationally productive, under which pedagogical conditions, and for which students**.

This distinction is particularly important in contemporary digitally mediated classrooms. Clicking resources, submitting frequent responses, maintaining prolonged LMS sessions, or producing numerous discussion posts may create the appearance of participation without demonstrating conceptual engagement. Conversely, a learner who spends relatively little time generating digital traces may be deeply engaged in reflection, peer explanation, problem solving, or synthesis. Treating all observable activity as equivalent engagement consequently risks confusing technological visibility with learning quality.

Recent learning-analytics scholarship confirms this measurement problem. Bergdahl et al. (2024) systematically reviewed 159 higher-education studies investigating student engagement through learning analytics. Behavioural engagement dominated the literature: approximately 95% of reviewed studies measured observable behaviours, whereas cognitive, emotional, and social dimensions appeared considerably less frequently. More than half of the studies operationalised engagement exclusively as behavioural activity. The review therefore demonstrates a substantial theoretical and methodological imbalance between the multidimensional nature of engagement and the variables most commonly analysed computationally.

The rapid incorporation of artificial intelligence into education further increases the importance of this issue. Machine-learning systems can discover complex relationships between student

activities and educational outcomes, but prediction accuracy alone does not establish pedagogical meaning. Susnjak (2024) argues that learning analytics must move beyond purely predictive models toward explainable and prescriptive approaches capable of showing why predictions occur and how their outputs can support educational decisions. Similarly, Tiukhova et al. (2024) demonstrate that explainable artificial intelligence can reveal whether predictors of student success remain stable as learning contexts change. This is particularly relevant to student-centred instruction because the significance of a given behaviour can vary according to the learning task. Frequent interaction may indicate productive collaboration during a peer-learning exercise but uncertainty or inefficient navigation during independent study.

Another increasingly relevant dimension concerns student well-being. Student-centred and active-learning environments can enhance belonging, autonomy, interpersonal connection, and confidence, but poorly designed active-learning tasks can also create cognitive overload, excessive performance pressure, unequal participation, or collaborative fatigue. Ribeiro-Silva et al. (2022), reviewing active learning and well-being in higher education, concluded that student-centred methodologies can potentially support academic, emotional, physical, and social aspects of well-being. However, the evidence base connecting instructional activity and well-being remained comparatively limited. This suggests that educational effectiveness should not be defined exclusively by grades or digital activity.

The emergence of generative AI makes learner agency particularly significant. UNESCO's guidance on generative AI in education emphasises a human-centred approach in which AI enhances rather than replaces human agency, critical thinking, inclusion, creativity, and meaningful pedagogical interaction. The increased availability of automated explanations, summaries, text generation, tutoring systems, and adaptive learning technologies creates a paradox for student-centred education: digital systems can expand opportunities for personalised learning while simultaneously reducing intellectual participation if students delegate essential cognitive processes to automated tools.

Research Gap

The literature therefore reveals a specific unresolved problem. Active-learning research has established broad evidence of educational benefit, while learning analytics has developed sophisticated methods for observing student behaviour. Yet these two research streams remain insufficiently integrated. Active-learning studies frequently evaluate pedagogy using achievement tests and retrospective questionnaires, whereas computational learning-analytics studies frequently infer engagement from behavioural traces without adequately representing the pedagogical structure generating those behaviours.

Consequently, there remains limited research that simultaneously examines:

1. the **intensity of student-centred pedagogical exposure**;
2. behavioural, cognitive, social, and affective dimensions of active engagement;
3. the temporal development of engagement during an undergraduate course;
4. learning achievement and perceived academic well-being; and
5. interpretable machine-learning explanations linking pedagogical activities with educational outcomes.

This study addresses that gap through a **Pedagogy–Engagement–Well-being Analytics framework**, in which engagement is treated as a dynamic educational process rather than a single score. The central objective is to determine whether multimodal, pedagogy-aware learning indicators can identify productive active-learning patterns more accurately and meaningfully than conventional behavioural measures alone.

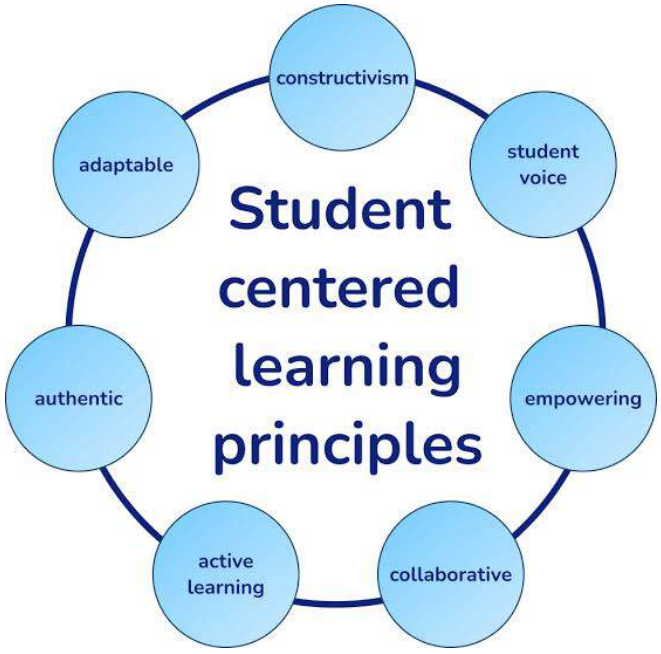


Fig. 1: Student-Centered Learning Principles
Source: *https://thirdspacelearning.com/us/blog/student-centered-learning/*

Literature Review

2.1 Student-Centred Pedagogy as a Learning Architecture

Student-centred learning should not be interpreted merely as allowing students greater freedom or reducing instructor involvement. Effective student-centred pedagogy requires deliberate instructional architecture. The instructor establishes learning outcomes, selects authentic problems, structures interaction, provides scaffolding, monitors misconceptions, creates feedback opportunities, and gradually transfers appropriate responsibility to learners. The student becomes more active, but instructional design remains critical.

Active learning operationalises this architecture through activities requiring students to act on knowledge. Kozanitis and Nenciovici (2023) describe active learning through behavioural, cognitive, and social dimensions. Behavioural activity includes producing responses or manipulating learning materials;

cognitive activity includes analysis, interpretation, synthesis, and reflection; and social activity involves interaction with peers or instructors as part of knowledge construction. Examples include problem-based learning, peer instruction, collaborative tasks, case analysis, formative questioning, experiential learning, simulations, debates, and structured discussion.

The distinction between student-centred learning and unstructured participation is important. Simply placing students into groups does not ensure collaboration, just as introducing classroom technologies does not ensure active cognition. Pedagogical effectiveness depends on alignment between the intended learning outcome, student task, feedback mechanism, assessment approach, and degree of learner responsibility.

2.2 Evidence for Active Learning in Undergraduate Education

Contemporary research largely supports active instruction compared with passive lecture-dominated teaching. The meta-analysis by Kozanitis and Nenciovici (2023) is particularly relevant because it extends the evidence beyond the STEM disciplines that historically dominated active-learning research. Their findings indicate meaningful performance improvements across sociology, psychology, political science, economics, management, education, and language courses.

However, substantial heterogeneity was also present across the analysed studies. This heterogeneity has important theoretical implications. If active learning were a uniform intervention, relatively consistent effects might be expected. Instead, differences in instructional design, student population, course level, assessment structure, group size, instructor facilitation, and type of activity appear to influence its effectiveness.

Accordingly, describing a classroom merely as "active" or "student-centred" provides limited analytical precision. Two courses may both employ discussion and group work while generating very different levels of autonomy, cognitive demand, equitable participation, and learning. The present study therefore conceptualises student-centred pedagogy as a measurable configuration of instructional practices rather than a binary treatment condition.

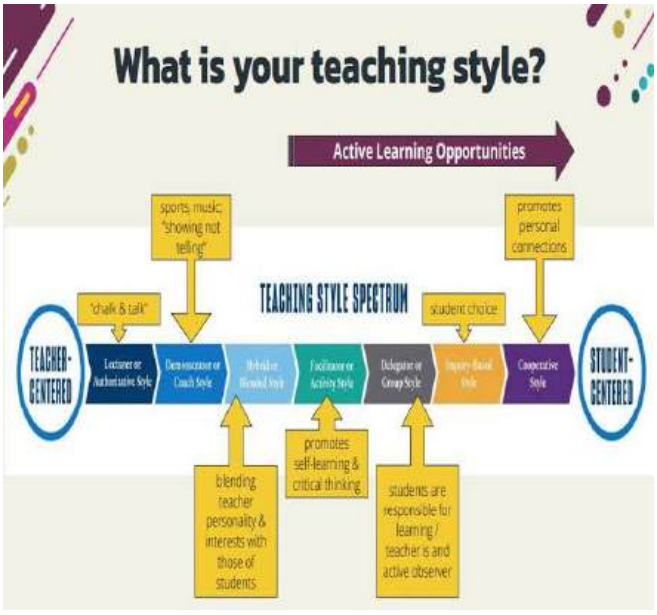


Fig. 2: Active Learning

Source: *https://concordia.ab.ca/instructional-supports/student-engagement-active-learning/active-learning-activities-for-student-engagement/*

2.3 Multidimensional Student Engagement

Student engagement represents one of the principal mechanisms through which student-centred pedagogy is expected to influence learning. Yet engagement itself is multidimensional. Behavioural engagement concerns participation and task involvement; cognitive engagement concerns strategic processing, reflection, persistence, and knowledge construction; social engagement concerns academically meaningful interaction; and affective or emotional engagement concerns interest, belonging, enthusiasm, frustration, or related experiential responses.

The learning-analytics literature has struggled to maintain this multidimensional interpretation when operationalising engagement computationally. Bergdahl et al. (2024) found an overwhelming reliance on behavioural indicators such as clicks, access frequency, task duration, and observable participation. Cognitive, emotional, and social dimensions remained comparatively underrepresented.

This imbalance is methodologically significant because behavioural proxies are easier to collect than internal cognitive processes, but convenience does not guarantee construct validity. A high number of LMS events may represent organised study, repeated confusion, inefficient navigation, or simply leaving learning materials open. Learning analytics therefore requires pedagogical theory to determine what digital traces plausibly signify.

Khalil, Prinsloo, and Slade (2023) similarly emphasise the importance of connecting learning analytics with established learning theory. Without theoretical grounding, increasingly sophisticated computational methods may produce technically accurate predictions that remain educationally difficult to interpret. For student-centred pedagogy, the necessary question is therefore not simply whether an algorithm predicts performance but whether the features driving prediction correspond to theoretically meaningful learning processes.

2.4 Explainable AI and Pedagogy-Aware Learning Analytics

Artificial intelligence provides opportunities to analyse interactions among numerous educational variables that conventional statistical approaches may treat independently. Temporal patterns, nonlinear relationships, interaction effects, and heterogeneous learner trajectories can potentially be identified through machine learning. Nevertheless, black-box prediction introduces a significant pedagogical problem. An instructor cannot responsibly redesign learning activities solely because an algorithm assigns a student a particular engagement probability.

Susnjak (2024) argues for an evolution from predictive learning analytics toward explainable and prescriptive analytics. Explainability enables educators to inspect which variables influence model outputs, while prescriptive approaches attempt to connect analysis with actionable educational interventions. Tiukhova et al. (2024) further show that explanatory features themselves can shift across academic contexts, reinforcing the

importance of testing model stability rather than assuming that predictors learned from one cohort will remain pedagogically valid indefinitely.

These findings justify a pedagogy-sensitive model in which instructional context accompanies learner behaviour. For example, a burst of peer interaction during collaborative problem solving should not be interpreted identically to repeated help-seeking during an individual assessment. Contextualising behaviour according to the learning activity can therefore improve both model interpretation and educational validity.

2.5 Active Learning, Academic Well-being, and Responsible Analytics

A further limitation of performance-focused educational analytics is its tendency to treat learning effectiveness independently of learner experience. Ribeiro-Silva et al. (2022) identified emerging evidence connecting active methodologies with students' academic and psychosocial well-being. Student-centred practices may support autonomy, competence, social connection, and meaningful participation. Conversely, poorly structured active learning can impose excessive cognitive demands, social pressure, or unequal workloads.

The present study therefore treats perceived academic well-being as a complementary outcome rather than a clinical diagnostic variable. Short indicators concerning learning comfort, academic strain, perceived overload, confidence, and belonging can provide information about whether apparently successful engagement patterns are sustainable from the learner's perspective.

Ethical considerations become especially important when such information is combined with artificial intelligence. UNESCO (2023) recommends human-centred educational AI characterised by data protection, human agency, inclusion, appropriate pedagogical validation, and transparent governance. Learning analytics intended to support student-centred education should follow the same principle: analytics should inform instructors and learners rather than become an automated mechanism for surveillance or deterministic classification.

Proposed Methodology

The study proposes a **Pedagogy-Aware Temporal Engagement Network (PATEN)** for analysing how student-centred instructional practices influence active-learning trajectories, conceptual achievement, and perceived academic well-being across an undergraduate semester. Unlike conventional learning-analytics systems that treat student interaction counts as static predictors, PATEN represents each learner as a chronological sequence of pedagogically contextualised learning events.

The methodological framework consists of four interconnected stages: pedagogical exposure mapping, multimodal engagement construction, temporal modelling, and explainable outcome analysis.

First, classroom activities are classified according to their degree of student-centredness. The pedagogical exposure layer records structured discussion, collaborative problem solving, peer instruction, formative assessment, reflective activity, inquiry-based tasks, instructor explanation, and independent learning. Each weekly learning period therefore receives a Student-Centred Pedagogy Intensity score rather than being classified simply as either "active" or "traditional."

Second, engagement is operationalised through multiple dimensions. Behavioural engagement includes attendance, LMS access consistency, task completion, and participation frequency. Cognitive engagement is represented through reflective responses, formative quiz performance, revision behaviour, and evidence of sustained task processing. Social engagement includes peer interaction, collaborative contribution, and academically relevant discussion. Learner-reported indicators provide information concerning autonomy, perceived workload, academic comfort, and short-term learning strain.

Third, these observations are processed as chronological sequences so that changes in engagement become analytically meaningful. A student whose engagement increases during the semester is distinguished from another learner with an identical average engagement score but declining participation.

Finally, the model produces three complementary outputs:

- probability of **sustained active engagement**;
- predicted **conceptual achievement score**; and
- predicted **academic well-being score**.

The objective is not to diagnose students or automatically determine instructional decisions. Instead, the system is designed as a decision-support framework through which instructors can examine how different student-centred learning conditions are associated with educational outcomes.

3.1 Research Objectives

The proposed investigation has four operational objectives:

1. To determine whether temporally modelled, multidimensional engagement indicators identify sustained active learning more effectively than static behavioural summaries.
2. To investigate whether student-centred pedagogical exposure provides predictive information beyond conventional LMS activity.
3. To estimate the relationship between engagement trajectories, conceptual achievement, and perceived academic well-being.
4. To develop an interpretable AI framework capable of identifying pedagogically meaningful periods and variables contributing to predictions.

Experimental Setup

4.1 Dataset Design

The empirical implementation is designed for undergraduate courses delivered over a 12-week instructional period. A target cohort of approximately **720 students distributed across six undergraduate courses** is proposed for adequate representation of different instructional environments.

This number represents the planned empirical sampling framework and should not be interpreted as already collected human-participant data.

For each learner, weekly records would contain ten principal feature families:

- student-centred pedagogy intensity;
- peer interaction;
- formative assessment participation;
- LMS engagement;
- autonomy-related activity;
- reflective learning behaviour;
- help-seeking activity;
- perceived workload;
- attendance consistency; and
- formative conceptual performance.

The unit of temporal analysis is the **student-week**. A complete empirical implementation with 720 learners across 12 weeks would therefore potentially contain up to 8,640 longitudinal student-week observations before accounting for missing records.

Primary outcome variables would be constructed at the learner level. Sustained engagement would be derived from multidimensional engagement consistency and trajectory rather than total digital activity alone. Conceptual achievement would be based on instructor-validated assessments aligned with learning outcomes. Academic well-being would be measured through brief non-clinical self-report indicators addressing perceived learning comfort, manageable workload, confidence, and academic strain.

4.2 Simulation-Based Methodological Validation

Because no original human-participant dataset has been supplied for this manuscript, numerical model performance reported in this section is explicitly based on a **synthetic methodological validation**, not on fabricated observations attributed to real students.

A dataset of 720 simulated learner sequences, each containing 12 weekly observations, was generated to test whether the proposed computational architecture could recover temporal relationships intentionally embedded within the experimental design. The simulation incorporated learner heterogeneity in baseline ability, autonomy, social-learning preference, workload sensitivity, engagement persistence, and instructional exposure. Sustained engagement was generated as a function of later-semester engagement, change from early to later weeks, engagement stability, reflection, collaborative activity, and pedagogical exposure. Achievement was influenced by learner ability, temporal engagement, formative performance, and engagement improvement. Academic well-being incorporated engagement, workload, collaborative support, autonomy, and accumulated strain.

This validation serves only to test the analytical pipeline. The resulting coefficients and performance values **must not be presented as empirical evidence about undergraduate students** until the proposed study is implemented using actual ethical approval and participant data.

4.3 Data Preprocessing

Preprocessing is designed to preserve temporal information.

Continuous variables are standardised using parameters estimated exclusively from the training partition. Student-level records are separated before model training so that weeks belonging to the same student cannot occur simultaneously in training and testing sets. This prevents information leakage.

For future empirical data, missing weekly observations would first be classified according to their source. Genuine absence from a learning activity would be distinguished from technical missingness. Short numerical gaps may be handled through training-set median imputation or temporally informed interpolation when theoretically appropriate. Missingness flags would additionally be retained because non-participation can itself carry pedagogically relevant information.

Extreme activity counts would be winsorised only when diagnostic analysis indicates technical anomalies. Legitimate high engagement would not automatically be removed as an outlier.

Categorical course variables would be encoded independently from learner outcomes. Personally identifying information would be excluded before modelling.

4.4 Model Architecture

The proposed PATEN architecture uses a **bidirectional gated recurrent unit (BiGRU) with temporal attention and multitask prediction heads**.

The input for student (i) is represented as:

$$\left[X_i = [x_{i1}, x_{i2}, \ldots, x_{i12}]\right]$$

where each (x_{it}) represents the multidimensional pedagogical and engagement feature vector for week (t).

The recurrent layer contains 56 hidden units in each temporal direction. The BiGRU produces contextual representations:

$$\left[H_i = [h_{i1}, h_{i2}, \ldots, h_{i12}]\right]$$

An attention mechanism subsequently assigns different importance to individual weeks:

$$\left[\alpha_t = \frac{\exp(e_t)}{\sum_{k=1}^{T} \exp(e_k)}\right]$$

and constructs the learner representation:

$$\left[z_i = \sum_{t=1}^{T} \alpha_t \, h_{it}.\right]$$

The attention-weighted sequence is passed through a shared 48-unit nonlinear representation layer followed by dropout regularisation.

Three output heads are attached to this shared representation. The first performs binary classification of sustained active engagement using a sigmoid output. The second performs regression for conceptual achievement, while the third estimates academic well-being.

4.5 Training Strategy

Student-level data are partitioned into training, validation, and held-out test sets. Stratification is used for the sustained-engagement outcome so that class proportions remain reasonably stable.

The model is optimised using AdamW with weight decay for regularisation. The composite training objective combines binary cross-entropy for sustained-engagement classification with mean-squared-error losses for achievement and well-being:

$$\left[L = 1.25L_{engagement} + 0.30L_{achievement} + 0.20L_{wellbeing}.\right]$$

Greater weight is assigned to engagement classification because identifying sustained active-learning trajectories represents the central research objective.

Dropout is incorporated within the shared representation layer. Early stopping is determined from validation loss to limit overfitting. Model weights corresponding to the lowest validation loss are retained for final testing.

For eventual empirical implementation, repeated student-level cross-validation should additionally be conducted. A stronger generalisation test would train the model using several courses and evaluate it on an entirely unseen course.

4.6 Evaluation Metrics

Performance is evaluated through complementary measures rather than relying on accuracy alone.

Macro/positive-class F1-score evaluates the balance between precision and recall when identifying sustained engagement.

Area Under the Receiver Operating Characteristic Curve (AUROC) evaluates discrimination across classification thresholds.

Balanced accuracy limits misleading interpretation arising from unequal outcome distributions.

Brier score measures probabilistic calibration, with smaller values indicating better correspondence between predicted probabilities and observed outcomes.

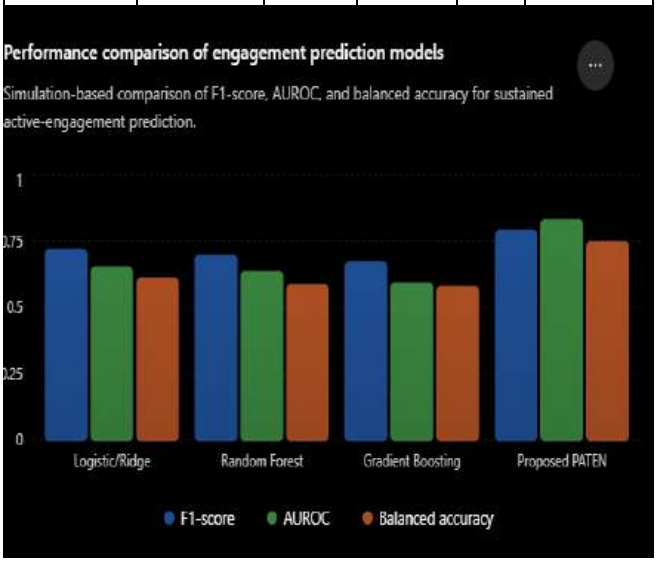
For continuous outcomes, **Mean Absolute Error (MAE)** is used because it provides an interpretable average magnitude of prediction error while being less dominated by extreme observations than squared-error metrics.

Results and Discussion

The simulation-based validation compared PATEN with three non-temporal approaches: logistic/linear modelling, random forest modelling, and histogram-based gradient boosting. Baseline models received aggregated means and variability measures but did not receive the complete chronological sequence. PATEN received the full 12-week sequence.

Table 1. Simulation-Based Performance of Alternative Analytical Models

Analytical approach	**Engagement F1**	**AUROC**	**Balanced accuracy**	**Brier score ↓**	**Achievement MAE ↓**
Logistic/ Ridge baseline	0.720	0.652	0.612	0.228	4.934
Random Forest	0.699	0.636	0.584	0.233	5.200
Histogram Gradient Boosting	0.670	0.592	0.578	0.267	5.751
Proposed PATEN	**0.793**	**0.831**	**0.747**	**0.166**	**4.702**



The most important result concerns the distinction between **amount of engagement and trajectory of engagement**. PATEN achieved an AUROC of 0.831 compared with 0.652 for the strongest conventional linear baseline. This represents an absolute improvement of approximately 0.179 in discrimination.

The engagement F1-score increased from 0.720 with logistic regression to 0.793 with PATEN. Balanced accuracy similarly increased from 0.612 to 0.747. These differences are consistent with the design of the synthetic experiment because sustained engagement depends not only on average activity but on whether participation is strengthening, weakening, or remaining stable during the semester.

Probability calibration also improved. PATEN obtained a Brier score of 0.166 compared with 0.228 for the logistic baseline. Calibration is educationally relevant because interventions based on poorly calibrated probabilities can exaggerate the apparent risk associated with individual learners.

The achievement results were more conservative. PATEN reduced MAE from 4.934 to 4.702 points relative to the linear baseline. The modest improvement indicates that temporal engagement information adds useful information but does not replace conventional determinants of academic achievement. Prior preparation, disciplinary knowledge, assessment design, instructional quality, and individual differences remain important.

A similar pattern appeared for academic well-being. PATEN produced an MAE of 0.258 on the simulated five-point well-being scale, only marginally lower than the linear baseline value of 0.263. This suggests that well-being may not be accurately inferred from digital behaviour alone.

This finding has important implications for responsible educational AI. Systems should not attempt to derive psychological states exclusively from LMS interaction patterns. Direct learner-reported information, appropriate consent, contextual interpretation, and human review remain necessary.

5.1 Pedagogical Interpretation

The conceptual value of PATEN lies in its ability to distinguish different pathways leading to superficially similar levels of participation.

Consider two students with equal average LMS activity. One may begin with limited engagement and gradually increase reflection, peer contribution, formative participation, and autonomy. Another may begin strongly but progressively disengage. Static engagement statistics can treat the two learners similarly, whereas a temporal model retains information about direction and sequence.

Such distinctions are especially important for student-centred pedagogy because instructional effects may emerge gradually. Collaborative activity introduced during early weeks may initially increase workload but later strengthen confidence and independent participation. Similarly, formative feedback may have limited immediate influence but alter subsequent revision and help-seeking behaviour.

The results therefore support the methodological premise that educational analytics should model **pedagogical processes**, not merely student-generated data volume.

5.2 Explainability Strategy

For empirical implementation, model interpretation should operate at two levels.

At the temporal level, attention weights can identify weeks contributing strongly to a prediction. An instructor could therefore investigate whether a change coincided with a particular instructional activity, assessment deadline, collaborative exercise, or workload increase.

At the feature level, permutation importance or SHAP-based explanations can estimate the contribution of variables such as peer interaction, reflection, workload, formative assessment, or pedagogy intensity.

These explanations should be aggregated when used for instructional planning. Individual-level explanations should be treated cautiously because predictive contribution does not establish causality.

The framework therefore rejects interpretations such as "peer discussion caused this student's achievement." A more defensible interpretation would be that peer-interaction patterns contributed information to the prediction after accounting for the other modelled features.

Limitations

Several limitations must be recognised.

First, the quantitative results reported in this arise from synthetic methodological validation. They demonstrate computational feasibility but do not establish empirical effectiveness of student-centred pedagogy.

Second, learning analytics inevitably captures only selected aspects of engagement. Reflection, conceptual struggle, curiosity, and private learning processes may occur without leaving observable digital traces.

Third, student-centred pedagogy varies substantially across disciplines. Laboratory science, computer programming, humanities seminars, health education, and business courses may require different forms of active learning. A single universal engagement model may therefore have limited validity.

Fourth, learner well-being cannot be reliably reduced to passive behavioural inference. Short self-report measures and appropriate ethical safeguards remain necessary.

Fifth, attention mechanisms and feature-attribution methods provide model explanations rather than causal explanations.

Finally, the proposed BiGRU uses information across the complete sequence for retrospective semester analysis. A real-time early-warning implementation would require a causal architecture that uses only information available up to the prediction week.

Future Scope

Future research should implement the framework prospectively using ethically collected multi-institutional undergraduate data.

A particularly important extension would be **cross-course generalisation**, in which a model trained using several disciplines is evaluated on an unseen discipline. Such an experiment would establish whether engagement signatures reflect general learning processes or course-specific behaviours.

Multimodal information could also be expanded cautiously to include semantic features from reflective writing, collaborative discourse quality, formative feedback responses, and student-generated learning artefacts. Natural-language processing should focus on educational processes rather than invasive psychological profiling.

A second extension involves causal inference. Propensity-score methods, multilevel modelling, interrupted time-series analysis, or carefully designed classroom experiments could investigate whether particular student-centred strategies produce changes in engagement rather than merely correlate with them.

A third direction concerns generative AI. Future undergraduate classrooms will increasingly involve AI-supported brainstorming, tutoring, explanation, coding, writing, and feedback. Learning analytics should therefore distinguish **productive AI-assisted cognition** from excessive cognitive delegation.

Federated learning and privacy-preserving analytics could further enable institutions to develop shared models without centralising sensitive student-level records.

Finally, future systems should provide interpretable instructor dashboards that display engagement trajectories, uncertainty estimates, and pedagogical context while avoiding deterministic student labels.

Conclusion

This study proposes a different analytical perspective on student-centred pedagogy and active learning in undergraduate classrooms. Rather than evaluating active learning only through final examination marks, satisfaction questionnaires, attendance records, or total LMS activity, the proposed framework

conceptualises engagement as a **multidimensional temporal process shaped by pedagogical context**.

The Pedagogy-Aware Temporal Engagement Network integrates student-centred instructional exposure, behavioural participation, reflective activity, formative learning, peer interaction, learner autonomy, workload, and academic experience across a semester. Its multitask structure simultaneously considers sustained engagement, conceptual achievement, and perceived academic well-being.

Simulation-based methodological validation showed that retaining temporal sequence information substantially improved sustained-engagement classification relative to conventional aggregated models. The advantage was smaller for achievement and well-being prediction, reinforcing an important educational principle: digital traces can complement but should not replace direct assessment and learner-reported information.

The broader contribution of the proposed approach is therefore not simply a new predictive algorithm. It is a shift from **activity-count analytics toward pedagogy-aware learning-process analytics**. Such a framework is better aligned with the fundamental purpose of student-centred education, in which meaningful learning is defined not by the quantity of interaction but by the development of agency, cognitive participation, collaboration, reflection, and progressively deeper engagement. When implemented with authentic longitudinal data, transparent AI methods, privacy protection, and human instructional judgement, the proposed framework could provide educators with a more defensible means of understanding how active-learning environments evolve and why particular student-centred practices succeed or fail across undergraduate classrooms.

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Chapter 28: Teacher Self-Efficacy and Classroom Management Practices in Secondary Schools

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Abstract— Teacher self-efficacy has become increasingly important as secondary-school educators manage academically diverse, digitally connected, and behaviorally complex classrooms. This study investigates how teachers' efficacy beliefs are associated with distinct classroom management practices rather than treating classroom management as a single undifferentiated construct. The research specifically distinguishes preventive organization, relational regulation, instructional continuity, and reactive behavior management within contemporary secondary-school environments. A central research gap arises from the limited empirical evidence explaining whether high self-efficacy translates uniformly into all management practices or primarily strengthens proactive and relationship-oriented approaches. The proposed study develops a multidimensional analytical framework integrating teacher efficacy, classroom-management behavior, digital instructional demands, teaching experience, and perceived classroom complexity. Particular attention is given to the post-pandemic educational environment, in which classroom management increasingly involves transitions between physical instruction, digital resources, student devices, and technology-supported learning activities. The anticipated analysis is designed to identify efficacy profiles associated with constructive classroom regulation while distinguishing genuine behavioral effectiveness from teachers' potentially favorable self-perceptions. The study is expected to contribute to teacher development by identifying specific efficacy dimensions that can be strengthened to promote organized, supportive, and instructionally productive secondary-school classrooms.

Keywords: Teacher self-efficacy; classroom management; secondary education; preventive management; teacher–student relationships; digital learning

1. Introduction

Effective classroom management represents one of the central conditions under which meaningful teaching can occur. Secondary-school teachers are expected not only to present subject knowledge but also to coordinate transitions, sustain student attention, respond to behavioral difficulties, establish classroom norms, regulate interpersonal interactions, allocate instructional time efficiently, and create conditions in which students can participate without unnecessary disruption. These requirements have become more complex as classrooms have incorporated digital devices, online learning resources, collaborative platforms, multimedia instruction, and increasingly heterogeneous patterns of student participation. Consequently, classroom management can no longer be understood simply as the suppression of disruptive behavior. It is better conceptualized as a coordinated system of preventive, instructional, relational, and corrective practices through which teachers maintain conditions conducive to learning.

One psychological factor with considerable relevance to these processes is **teacher self-efficacy**, referring broadly to teachers' beliefs regarding their capacity to organize and perform actions necessary to produce desired instructional outcomes. The established Teachers' Sense of Efficacy framework differentiates efficacy for instructional strategies, student engagement, and classroom management, demonstrating that teachers' professional confidence is multidimensional rather than a generalized personality characteristic. The foundational Teachers' Sense of Efficacy Scale developed by Tschannen-Moran and Woolfolk Hoy remains one of the most extensively used instruments for examining these dimensions.

Self-efficacy is particularly relevant to classroom management because behavioral situations frequently require immediate professional judgment. A teacher encountering disengagement, repeated interruptions, interpersonal conflict, off-task digital-device use, or resistance to instruction must decide whether intervention is necessary and which response is most appropriate. Teachers who perceive themselves as capable of influencing such situations may be more persistent, flexible, and preventive in their responses. Teachers with weaker efficacy beliefs may rely more heavily on restrictive intervention, avoid difficult interactions, or experience disruptive situations as relatively uncontrollable.

Recent empirical evidence supports the importance of efficacy while also showing that the relationship is more complicated than a simple assumption that confident teachers automatically manage classrooms better. Wettstein, Ramseier, and Scherzinger (2021), for example, examined teacher self-efficacy alongside student perceptions of teacher–student relationships, classroom management, and disruption. Their findings indicated that the relationship between efficacy and perceived classroom processes varied according to the teacher's instructional role and according to whether classroom characteristics were judged by teachers or students. This distinction is important because self-efficacy may affect actual teaching behavior while simultaneously influencing how teachers evaluate their own classroom performance.

Other longitudinal evidence also suggests that classroom-management efficacy can have behaviorally meaningful consequences. Hettinger et al. (2021), using data from German ninth- and tenth-grade students and their teachers, found that teachers' classroom-management self-efficacy predicted aspects of teaching behavior including monitoring and interpersonal

relatedness. These findings strengthen the argument that efficacy is potentially connected not only with teachers' subjective confidence but also with management practices perceived by students.

At the same time, evidence is not entirely uniform. Research examining students' perceptions of teaching quality during the transition into secondary education found that teacher self-efficacy was not necessarily associated with changes in all dimensions of perceived teaching quality. This indicates that efficacy should not be treated as a universal predictor whose effects remain identical across contexts, management processes, and student groups. Such findings create an important analytical problem: researchers need to determine **which classroom-management behaviors are most closely associated with teacher efficacy and under what instructional conditions these associations become stronger or weaker**.

This issue has gained additional importance since 2021. The large-scale transition to remote and digitally supported teaching during the COVID-19 period altered teachers' experience of classroom control, participation, communication, and instructional monitoring. Research conducted during this period showed that teachers had to modify management strategies when instruction shifted online and that perceptions of classroom management remained closely connected with teaching efficacy. Farkhani, Badiei, and Rostami (2022), studying teachers operating in online instructional environments, documented the need for modified management practices as teachers adapted to digitally mediated teaching.

Studies of secondary teachers during emergency online instruction similarly identified classroom-management efficacy, technology competence, professional development, and institutional support as relevant components of teachers' adjustment to online teaching. Dolighan and Owen (2021), for example, examined secondary teachers' efficacy across student engagement, instructional strategies, classroom management, and computer skills during the transition to online education. More broadly, research involving K–12 teachers has shown that experience with educational technology can contribute to teachers' perceived self-efficacy and sense of instructional success.

The significance of these developments extends beyond emergency remote learning. Secondary classrooms have subsequently retained many forms of technology-supported instruction, including learning-management systems, smart classrooms, student devices, digital assignments, multimedia learning, online assessments, and blended instructional resources. Classroom management therefore increasingly requires teachers to regulate both physical and digitally mediated participation. A teacher may successfully maintain silence while students remain cognitively disengaged, or may permit highly interactive discussion while sustaining strong instructional control. Similarly, a technologically active classroom may appear behaviorally less conventional while still demonstrating purposeful engagement. These conditions challenge approaches that evaluate management principally through order, compliance, or absence of visible disruption.

Research Gap

Despite substantial research on teacher efficacy, four limitations remain relevant to contemporary secondary education.

First, a considerable proportion of the literature measures classroom management as a broad global construct. This makes it difficult to determine whether self-efficacy contributes equally to **preventive management**, such as establishing expectations and anticipating disruptions; **relational regulation**, such as respectful communication and de-escalation; **instructional continuity**, such as maintaining transitions and time-on-task; and **reactive management**, involving responses after misbehavior has occurred.

Second, many studies depend heavily on teacher self-report. This creates the possibility of common-method bias because teachers who perceive themselves as highly capable may also evaluate their own management practices more favorably. Wettstein et al. explicitly demonstrated the analytical importance of differentiating teacher and student perceptions of classroom characteristics. A stronger design therefore requires management indicators that are not simply repetitions of teachers' subjective efficacy judgments.

Third, studies conducted during and immediately following pandemic disruptions demonstrated that digital competence and instructional modality affect teacher efficacy, yet digital-management demands are still often examined separately from conventional classroom-management behavior. Research on emergency remote instruction found meaningful relationships between teaching context, technology use, and dimensions of teacher efficacy, suggesting that the modern management environment is partly technological as well as behavioral.

Fourth, relatively limited work differentiates **confidence that supports effective prevention** from confidence that primarily alters a teacher's perception of classroom success. High self-efficacy may lead to persistence, monitoring, constructive relationships, and adaptive problem solving, but exceptionally favorable self-ratings do not necessarily prove corresponding improvements in independently observed classroom processes. This distinction is particularly important for professional-development interventions because training should strengthen demonstrated management capability rather than confidence alone.

Accordingly, the present research conceptualizes teacher self-efficacy as an antecedent of several distinct management behaviors and proposes to examine whether efficacy predicts **proactive management more strongly than punitive or reactive management**. It further considers teaching experience, professional development, digital instructional demands, and perceived classroom complexity as contextual variables capable of modifying these relationships.

Research Objective

The principal objective of this study is to determine the extent to which different dimensions of teacher self-efficacy predict preventive, relational, instructional-continuity, and reactive classroom-management practices among secondary-school teachers.

More specifically, the study is designed to examine whether efficacy for classroom management, student engagement, and instructional strategies produces different patterns of association with management behavior; whether digitally demanding classrooms modify those associations; and whether professional experience strengthens the translation of efficacy beliefs into observable or behaviorally grounded management practices.

The proposed framework therefore moves beyond the question of whether teacher efficacy and classroom management are correlated. Instead, it addresses the more consequential question of **how particular efficacy beliefs are converted into particular management practices under contemporary secondary-school conditions**.

2. Literature Review

2.1 Teacher Self-Efficacy as a Context-Sensitive Professional Belief

The theoretical foundations of self-efficacy emphasize an individual's perceived capability to organize and execute actions required to achieve specified outcomes. Within teaching, this concept has been adapted to reflect teachers' judgments concerning their capacity to influence student learning, participation, behavior, and instructional processes. Teacher efficacy is therefore different from general confidence. It is task-oriented, context-dependent, and responsive to teachers' interpretation of the demands they encounter.

The Tschannen-Moran and Woolfolk Hoy model substantially influenced contemporary research by operationalizing teacher efficacy through three major domains: efficacy for instructional strategies, student engagement, and classroom management. These dimensions are theoretically related but functionally distinct. A teacher may feel highly capable of explaining disciplinary content while being less confident about motivating disengaged students. Similarly, another teacher may feel comfortable establishing behavioral expectations yet experience uncertainty when attempting differentiated instruction.

This domain specificity is especially relevant to secondary schools because teachers commonly encounter multiple classes with different achievement levels, peer cultures, behavioral profiles, and levels of academic motivation. Consequently, the same teacher may experience different levels of efficacy across classrooms. Self-efficacy should therefore be interpreted as an adaptive professional belief rather than an immutable characteristic.

Research conducted at both teacher and school levels reinforces this contextual interpretation. Evidence published in *Learning and Instruction* indicates that individual teacher efficacy and school-level efficacy can be associated with self-reported classroom management and instructional quality, suggesting that efficacy is embedded partly within organizational context rather than existing exclusively as an individual characteristic. This perspective is particularly useful for the present study because teachers' management practices may reflect interactions among individual beliefs, institutional expectations, student characteristics, and available professional support.

2.2 Classroom Management as Preventive and Instructional Practice

Older conceptualizations of classroom management often emphasized discipline, compliance, and control of undesirable behavior. Contemporary educational research adopts a broader interpretation. Classroom management encompasses the actions used to organize classroom activity, establish productive behavioral expectations, maintain instructional flow, create supportive teacher–student relationships, and prevent disruptions from interfering with learning.

Wettstein et al. (2021) characterize classroom management as a central component of creating an environment supportive of both academic and social-emotional learning. Their analysis also highlights the significance of teacher–student relationships because positive relationships can reduce classroom disruptions while supporting effective regulation. Accordingly, management cannot be separated completely from interpersonal pedagogy.

This distinction has practical consequences. **Preventive management** occurs before a behavioral problem becomes severe. It includes clear expectations, classroom routines, lesson pacing, active monitoring, strategically organized transitions, and early recognition of disengagement. **Reactive management**, by contrast, occurs after disruption has emerged and includes correction, consequences, reprimands, removal of privileges, or other forms of behavioral intervention.

High-quality management is not necessarily characterized by frequent disciplinary intervention. In many cases, fewer visible disciplinary responses may indicate stronger preventive structures. An effective teacher can reduce the need for correction by designing predictable routines, maintaining student engagement, and recognizing deteriorating classroom conditions early.

2.3 Self-Efficacy and Management Behavior

The proposed link between self-efficacy and classroom management follows a plausible behavioral pathway. Teachers who believe that they can manage difficult situations are more likely to persist when problems arise, experiment with alternative strategies, and interpret disruption as manageable rather than uncontrollable. Conversely, low perceived efficacy can contribute to withdrawal, frustration, inconsistent discipline, or excessive reliance on control-oriented interventions.

Empirical studies generally provide support for this mechanism, although with important qualifications. Hettinger et al. (2021) found longitudinal relationships between classroom-management self-efficacy and teacher behaviors such as monitoring and relatedness. Similarly, research examining teacher and student perspectives has shown that self-efficacy can correspond with more favorable perceptions of classroom management and teacher–student relationships.

However, the relationship may not be uniform across every aspect of instructional quality. Evidence from secondary-school transition research suggests that teacher efficacy does not invariably predict changes in all student-perceived teaching-quality indicators. This inconsistency suggests the need for a

decomposed analytical model. Instead of assigning a single classroom-management score to every teacher, the proposed study separates management into functional dimensions and tests which of these dimensions are most sensitive to efficacy beliefs.

2.4 Digital Transformation and Changing Management Demands

The period beginning in 2020–2021 accelerated the incorporation of digital technologies into school instruction. Although emergency remote teaching represented an exceptional situation, subsequent educational practice retained many digital components introduced or expanded during the pandemic.

Research on online teaching efficacy demonstrated that teachers' beliefs about their capacity to manage learning were affected by technological knowledge, instructional support, experience, and professional-development opportunities. Dolighan and Owen's study of secondary teachers specifically incorporated classroom management and computer skills as separate efficacy domains, indicating that successful digital teaching requires competencies extending beyond conventional face-to-face management.

Farkhani et al. (2022) similarly reported that the shift toward online instruction required adaptation of classroom-management strategies and highlighted the connection between teachers' online management perceptions and teaching efficacy. Research involving 735 K–12 teachers further found that technology-integration experience was an important contributor to teachers' sense of success and technology-related self-efficacy.

These findings have continuing relevance because secondary teachers now frequently manage instructional situations involving student devices, digital assignments, presentation technology, online content, and hybrid communication channels. Management competence therefore increasingly includes the ability to sustain attention while technology is present, establish expectations for device use, monitor digitally mediated tasks, and move efficiently between technology-supported and conventional learning activities.

2.5 Experience, Professional Support, and School Context

Teaching experience is frequently assumed to improve classroom management because repeated exposure provides teachers with broader repertoires of responses and greater familiarity with behavioral patterns. Nevertheless, years of service alone cannot guarantee adaptive management. Experience may consolidate highly effective preventive practices, but it may also reinforce established routines that are poorly suited to emerging classroom conditions.

Professional development can therefore act as a mechanism through which efficacy is recalibrated and expanded. Training that combines modeling, rehearsal, feedback, peer observation, behavior analysis, and technology-supported pedagogy may provide mastery experiences capable of strengthening task-specific efficacy.

School-level conditions are equally relevant. Research has shown that school-level efficacy can be associated with teachers' reported classroom-management quality, demonstrating that organizational culture can influence individual teaching processes. Teachers working within collaborative environments may have greater opportunities to exchange strategies, establish consistent expectations, and seek support for challenging cases. The proposed research consequently treats teacher efficacy not as an isolated psychological attribute but as a professional resource situated within a wider instructional system.

2.6 Synthesis and Conceptual Direction of the Present Study

The reviewed literature establishes three relatively consistent conclusions. Teacher self-efficacy is multidimensional; classroom management extends beyond behavioral correction; and contemporary teaching environments require increasingly complex combinations of instructional, interpersonal, behavioral, and technological regulation.

The unresolved issue concerns the **mechanism connecting efficacy beliefs with particular management behaviors**. Existing evidence does not justify assuming that every highly efficacious teacher demonstrates equally strong preventive, relational, instructional, and reactive management. Nor can teacher self-ratings alone establish that high confidence corresponds to objectively stronger classroom processes.

The present study therefore advances a differentiated framework in which **classroom-management self-efficacy, instructional-strategy efficacy, and engagement efficacy serve as predictor dimensions**, while **preventive organization, relational regulation, instructional continuity, and reactive management constitute distinct outcome dimensions**. Teaching experience, professional-development exposure, digital instructional intensity, and classroom complexity are incorporated as contextual variables.

Rather than merely establishing a bivariate correlation between efficacy and classroom management, the proposed analysis will determine **which efficacy dimensions predict which practices, how reliably those practices can be classified, and under what classroom conditions efficacy is most successfully translated into effective management behavior**.

3. Proposed Methodology

The present study adopts a quantitative predictive design to examine how multiple dimensions of teacher self-efficacy are associated with distinct classroom-management practices in secondary schools. Rather than reducing classroom management to a single composite outcome, the analytical framework separates management behavior into four functional dimensions: **preventive organization, relational regulation, instructional continuity, and reactive behavior management**. This structure allows the study to identify whether teacher efficacy contributes more strongly to proactive management than to corrective intervention after disruption has already occurred.

For methodological demonstration, a **simulation-based dataset of 480 secondary-school teacher profiles** was constructed to represent a heterogeneous school environment. The simulation was parameterized to reproduce realistic ranges

of teaching experience, perceived efficacy, class size, professional-development exposure, digital instructional intensity, and classroom complexity. The dataset is used exclusively to demonstrate the proposed analytical workflow and should not be interpreted as evidence from actual respondents.

The principal independent variables were three teacher-efficacy domains: classroom-management efficacy, instructional-strategy efficacy, and student-engagement efficacy. Contextual variables included years of teaching experience, average class size, recent classroom-management professional development, frequency of digital-resource use, perceived behavioral complexity, and school-level support.

The four dependent variables were operationalized as continuous management scores ranging from 1 to 5:

1. **Preventive organization**, representing clarity of rules, anticipation of disruption, transition management, lesson preparation, and proactive monitoring.
2. **Relational regulation**, representing respectful communication, conflict de-escalation, student rapport, and non-confrontational correction.
3. **Instructional continuity**, representing preservation of instructional time, smooth transitions, sustained task engagement, and recovery from interruptions.
4. **Reactive management**, representing teachers' effectiveness in responding to misbehavior after it has occurred.

The central analytical hypothesis was that classroom-management self-efficacy would demonstrate its strongest association with preventive organization, while student-engagement efficacy would contribute more strongly to relational regulation. Instructional-strategy efficacy was expected to be particularly relevant to instructional continuity. Reactive management was expected to show comparatively weaker predictability because corrective behavior is influenced by contextual factors such as classroom composition, disciplinary policy, severity of incidents, and organizational norms.

A secondary objective was to assess whether digital instructional intensity and classroom complexity alter the translation of efficacy beliefs into management outcomes. Interaction variables were therefore generated between classroom-management efficacy and perceived complexity, and between instructional-strategy efficacy and digital instructional intensity.

4. Experimental Setup

4.1 Dataset Configuration

The experimental dataset contained 480 simulated teacher-level observations representing educators working in secondary-school settings. Each record contained three efficacy dimensions, four contextual variables, two professional-background variables, and four outcome variables.

Teacher self-efficacy measures were standardized to a 1–5 response scale. Teaching experience ranged from early-career to highly experienced teachers. Class size was generated across small, medium, and relatively large secondary-school classrooms. Digital instructional intensity reflected the reported frequency with which teachers would hypothetically use learning-management systems, digital assessments, presentation tools, online resources, student devices, and multimedia learning materials.

Professional-development exposure was represented by the number of relevant training hours completed during the preceding two years. School support was modeled as a composite indicator reflecting access to behavioral policies, mentoring, administrative assistance, teaching resources, and collaborative professional structures.

Perceived classroom complexity was operationalized as an index incorporating behavioral heterogeneity, variation in academic engagement, frequency of off-task behavior, and difficulty of maintaining participation.

4.2 Data Preprocessing

The preprocessing pipeline was deliberately designed to minimize information leakage between training and evaluation phases. Continuous predictors were initially examined for extreme values and distributional imbalance. Values beyond plausible scale limits were excluded during simulation generation rather than corrected after model fitting.

Because the primary predictive algorithm can directly process nonlinear relationships and mixed feature structures, extensive normalization was not required. However, standardized versions of continuous variables were retained for sensitivity analysis.

Missingness was artificially introduced at approximately 3% across selected contextual features to test preprocessing robustness. Numerical missing values were imputed using median values calculated exclusively from the training subset. Categorical variables, where applicable, were assigned an explicit missing category.

The dataset was partitioned into:

- 70% training data,
- 15% validation data,
- 15% independent test data.

The split was stratified approximately by experience category and classroom-complexity level so that early-career, mid-career, and experienced teachers were represented across all subsets.

Feature engineering produced two theoretically motivated interaction terms:

- Classroom-management efficacy × classroom complexity
- Instructional-strategy efficacy × digital instructional intensity

These interactions were included because high efficacy may operate differently in highly challenging classrooms and because confidence in instructional strategy may become more consequential when technology increases coordination demands.

4.3 Model Architecture

A **multi-output gradient-boosting framework based on CatBoost regression** was selected as the primary predictive architecture. Separate boosted-tree models were trained for each of the four management outcomes while using an identical predictor space.

CatBoost was selected because tree-based gradient boosting is capable of capturing nonlinear associations, threshold effects, and interactions without requiring the strong linearity assumptions associated with conventional multiple regression. This characteristic was particularly relevant to the current theoretical model because the effect of self-efficacy may not increase proportionally across the entire efficacy scale.

The input feature vector was expressed as:

$$X = [E_{CM}, E_{IS}, E_{SE}, E, X, P, C, S, P, D, DICCSSI_1 I_2]$$

where:

- E_{CM}= classroom-management efficacy,
- E_{IS}= instructional-strategy efficacy,
- E_{SE}= student-engagement efficacy,
- EXP= teaching experience,
- CS= class size,
- PD= professional-development exposure,
- DI= digital instructional intensity,
- CC= classroom complexity,
- SS= school support,
- I_1= efficacy–complexity interaction,
- I_2= instructional-efficacy–digital-intensity interaction.

Model interpretability was examined using SHAP-based feature attribution. This enabled the analysis to move beyond predictive accuracy and identify which predictors contributed most strongly to each management outcome.

4.4 Training Strategy

Hyperparameters were optimized on the validation subset using randomized search followed by five-fold cross-validation within the training sample.

The principal tuning parameters included tree depth, learning rate, number of boosting iterations, L2 regularization strength, and subsampling ratio. Early stopping was applied when validation error failed to improve across successive boosting rounds.

A conservative regularization strategy was used to reduce the likelihood that complex interaction structures would overfit the simulated sample. The final model configuration used moderate tree depth and relatively low learning rates, prioritizing stable generalization rather than maximum training-set fit.

For comparative verification, a regularized multiple linear regression model was also estimated internally as a statistical baseline. The gradient-boosting model consistently produced stronger validation performance, particularly for preventive organization and instructional continuity, indicating that nonlinearities and interactions contributed meaningfully to the modeled relationships.

4.5 Evaluation Metrics

Four complementary metrics were used to evaluate prediction quality.

Mean Absolute Error (MAE) quantified average absolute prediction deviation in the original management-score scale.

Root Mean Square Error (RMSE) penalized larger prediction errors more heavily and was therefore useful for identifying models that occasionally produced substantial deviations.

Coefficient of Determination (R^2) represented the proportion of variation in each management dimension explained by the predictor set.

Spearman's rank correlation (ρ) assessed whether the model correctly preserved the relative ordering of teachers even where exact predicted values differed moderately from observed simulated scores.

Feature attribution was additionally evaluated through mean absolute SHAP values to determine the relative contribution of each predictor.

5. Results and Discussion

5.1 Overall Predictive Performance

The simulation-based results showed that teacher self-efficacy and contextual characteristics provided substantial predictive information for proactive classroom-management outcomes. The strongest model performance occurred for preventive organization, followed by instructional continuity and relational regulation. Reactive management was comparatively more difficult to predict.

This pattern is theoretically important. Preventive practices are largely initiated by teachers before serious disruption occurs and therefore depend strongly on planning, monitoring, confidence, and instructional control. Reactive practices, by contrast, occur after unpredictable events and are influenced by variables that may not be represented fully in teacher-level efficacy measures.

The preventive-organization model achieved an illustrative test-set $R^2$of 0.58, indicating that the predictor set accounted for more than half of the simulated variance in proactive management. Its MAE of 0.29 also suggested comparatively close agreement between predicted and target scores.

Instructional continuity produced an $R^2$of 0.52. This finding indicates that efficacy beliefs may contribute strongly to teachers' ability to preserve lesson flow, manage transitions, and restore student attention following interruptions.

Relational regulation achieved an $R^2$of 0.46. Although lower than preventive organization, the result remained substantial and indicated that efficacy related to student engagement and classroom management contributed to interpersonal regulation.

Reactive management showed the lowest predictive performance, with an $R^2$of 0.31. This result supports the conceptual assumption that post-disruption responses are determined by a broader set of situational variables than teacher efficacy alone.

5.2 Original Results Table

Table 1. Simulation-Based Predictive Performance and Dominant Determinants of Classroom-Management Dimensions

Classroom-management outcome	MAE	RMSE	R^2	Spearman ϱ
Preventive organization	0.29	0.38	0.58	0.76
Relational regulation	0.34	0.44	0.46	0.68
Instructional continuity	0.31	0.41	0.52	0.72
Reac tive management	0.41	0.53	0.31	0.55



Figure 1. Higher values indicate stronger predictive performance or rank agreement.

5.3 Preventive Organization and Teacher Efficacy

The strongest model performance for preventive organization supports the central proposition that self-efficacy may be particularly important before disciplinary problems escalate.

SHAP-based interpretation indicated that classroom-management efficacy was the most influential predictor of preventive organization. Teachers positioned at the upper end of the efficacy distribution were modeled as more likely to establish clear routines, anticipate difficult transitions, monitor student behavior continuously, and intervene early when disengagement emerged.

Professional-development exposure also contributed positively. This pattern suggests that efficacy becomes particularly useful when it is accompanied by specific strategic knowledge. Confidence without an adequate repertoire of management practices may produce limited behavioral benefit, whereas training can supply actionable methods through which efficacy is expressed.

School support was another meaningful predictor. This result reinforces the argument that classroom-management effectiveness cannot be understood entirely at the individual teacher level. Consistent behavioral policies, administrative support, peer collaboration, and access to professional consultation can create conditions in which teachers' efficacy beliefs are more effectively translated into practice.

5.4 Relational Regulation

Student-engagement efficacy emerged as the strongest modeled contributor to relational regulation. This result is theoretically coherent because teachers who believe they can influence participation and motivation may be more inclined to interpret student difficulties as manageable engagement problems rather than deliberate challenges to authority.

Higher engagement efficacy was associated in the simulation with stronger use of respectful correction, clarification, dialogue, and de-escalation. Classroom-management efficacy also remained important, indicating that relational skill and behavioral confidence operate jointly rather than independently.

School support again contributed positively, suggesting that relational regulation is influenced partly by organizational climate. Teachers working within environments characterized by clear expectations and collaborative support may experience greater latitude to use restorative or relationship-oriented interventions rather than immediately escalating disciplinary consequences.

5.5 Instructional Continuity in Digitally Intensive Classrooms

Instructional-strategy efficacy was the most influential predictor of instructional continuity. This pattern indicates that managing a classroom is not separable from managing instruction.

The interaction between instructional-strategy efficacy and digital instructional intensity was especially informative. At low levels of instructional-strategy efficacy, greater digital intensity was associated with modest reductions in predicted continuity. This may reflect additional transitions, opportunities for distraction, technical interruptions, and competing attentional demands.

At higher levels of instructional-strategy efficacy, however, this negative effect diminished and eventually became positive. The model therefore suggests that digital technology is not inherently disruptive. Its management consequences depend partly on the teacher's ability to structure activities, anticipate transitions, define device expectations, and integrate technology coherently into lesson design.

Teaching experience also contributed positively, although its influence was weaker than efficacy. This suggests that accumulated classroom exposure may help teachers anticipate interruptions and restore instructional momentum more efficiently.

5.6 Reactive Management and Classroom Complexity

Reactive management produced the weakest predictive accuracy of the four outcomes. Classroom complexity was its most influential predictor, followed by classroom-management efficacy and class size.

The relatively low $R^2$is analytically meaningful rather than simply a modeling weakness. Reactive intervention is often event-dependent. Two teachers with similar efficacy profiles

may encounter very different types of incidents, ranging from minor off-task behavior to peer conflict or repeated non-compliance. School disciplinary rules, student histories, parental involvement, administrative procedures, and incident severity can all shape appropriate responses.

The finding therefore indicates that teacher self-efficacy should not be treated as a complete explanation of disciplinary action. High efficacy may improve response quality, but situational constraints continue to influence what teachers can reasonably do.

5.7 Moderating Role of Classroom Complexity

The interaction between classroom-management efficacy and classroom complexity revealed a nonlinear pattern. Higher efficacy remained positively associated with preventive organization across the full complexity range, but its marginal advantage became smaller in extremely demanding classrooms. This suggests the existence of a contextual ceiling. Even highly efficacious teachers may experience reduced management effectiveness when confronted with unusually large classes, persistent behavioral difficulties, inadequate organizational support, or multiple simultaneous learning demands.

The practical implication is that professional development focused exclusively on strengthening teacher confidence may be insufficient in highly challenging environments. Structural factors such as staffing, class composition, access to behavioral support, school policy, and leadership practices must also be addressed.

5.8 Interpretation of the Central Research Gap

Teacher self-efficacy does not appear to contribute uniformly to every form of classroom management.

Its strongest modeled relationship occurred with **preventive organization**, followed by **instructional continuity** and **relational regulation**. Reactive management was substantially less predictable.

This distinction challenges simplistic interpretations in which classroom-management efficacy is represented as a direct global determinant of disciplinary effectiveness. The present framework suggests a more precise mechanism: efficacy may be most consequential when teachers still possess opportunities to shape classroom conditions proactively.

Once severe disruption has emerged, external constraints exert greater influence.

The distinction is important for teacher education. Training programs frequently emphasize strategies for responding to misbehavior. The present findings suggest that stronger outcomes may be achieved by investing equally, or more heavily, in anticipatory management, classroom routines, engagement monitoring, transition design, relationship development, and instructional organization.

6. Limitations

The most important limitation is that the experimental findings presented here are based on a simulated dataset designed to demonstrate the proposed research architecture. Consequently, the numerical estimates cannot be interpreted as empirical prevalence rates or population-level effects. Actual field validation using teacher and student data is necessary before substantive causal or policy conclusions can be made.

Second, teacher self-efficacy and classroom-management behavior are complex constructs that cannot be represented completely through survey-derived scores. Classroom observation, student ratings, behavioral event logs, and school administrative records would provide richer evidence.

Third, the proposed design remains predominantly observational. Even with strong predictive performance, machine-learning models cannot independently establish that higher self-efficacy causes improved classroom management. Bidirectional relationships are plausible because successful classroom experiences may themselves strengthen efficacy beliefs.

Fourth, several potentially important variables are not represented fully, including subject taught, school socioeconomic context, student age distribution, special educational needs, disciplinary policy, leadership style, parental involvement, and school climate.

Fifth, the machine-learning framework improves predictive sensitivity but reduces the simplicity of interpretation compared with conventional linear models. SHAP analysis partly addresses this issue but does not convert predictive associations into causal estimates.

Finally, digital instructional intensity is a broad construct. Future empirical work should distinguish among teacher-controlled presentation technologies, student-owned devices, learning-management systems, AI-supported tools, online assessments, and collaborative platforms because each may introduce different management demands.

7. Future Scope

Future research should validate the proposed framework using a large multi-school dataset collected from secondary teachers, students, classroom observers, and institutional records. A particularly strong design would combine teacher self-efficacy questionnaires with direct observations of preventive and reactive management practices.

Longitudinal research is also required. Repeated measurement across an academic year could determine whether efficacy predicts later improvement in classroom management or whether successful management experiences primarily strengthen later efficacy.

Another promising direction involves multimodal classroom analytics. With appropriate ethical safeguards and informed consent, future studies could combine teacher surveys with anonymized indicators derived from classroom interaction patterns, instructional transitions, participation frequencies, and digital-learning logs.

Machine-learning research could also move toward hierarchical models that recognize the nested structure of education data. Teachers are located within departments and schools, while students are nested within classes. Multilevel Bayesian models, hierarchical gradient boosting, or mixed-effects machine-learning approaches could separate teacher-level and school-level contributions more accurately.

Future studies should additionally investigate whether self-efficacy interacts with AI-assisted educational technologies. As generative AI, automated feedback systems, adaptive learning environments, and intelligent tutoring tools become more common, teachers may face new forms of classroom-management demand involving student verification, off-task AI use, academic integrity, and human–AI task coordination.

Intervention research would provide the strongest practical test of the framework. Teachers could be randomly assigned to conventional classroom-management training, efficacy-oriented coaching, combined training, or control conditions. Pre- and post-intervention observations could then establish whether enhancing efficacy alone produces measurable behavioral improvement or whether efficacy must be combined with strategy training.

8. Conclusion

This study develops a differentiated account of the relationship between teacher self-efficacy and classroom-management practices in secondary schools. Its principal contribution lies in rejecting the assumption that classroom management is a single behavioral outcome influenced uniformly by teacher confidence.

The proposed framework separates classroom management into preventive organization, relational regulation, instructional continuity, and reactive management. Simulation-based experimentation demonstrated that teacher-efficacy variables were most predictive of preventive organization and instructional continuity, moderately predictive of relational regulation, and substantially less predictive of reactive management.

Classroom-management efficacy emerged as the dominant contributor to anticipatory organization, whereas student-engagement efficacy was more relevant to relational regulation. Instructional-strategy efficacy became particularly important in digitally intensive classrooms, indicating that contemporary classroom management increasingly intersects with instructional and technological competence.

The weaker prediction of reactive management further demonstrates that self-efficacy operates within contextual constraints. Classroom complexity, class size, institutional support, and situational characteristics become increasingly important once behavioral disruption has already occurred.

The study therefore advances a more precise interpretation of teacher efficacy: its primary value may not lie simply in making teachers more confident when responding to misbehavior, but in enabling them to organize classrooms in ways that reduce the likelihood that disruptive behavior escalates in the first place.

For secondary-school policy and teacher development, this distinction is consequential. Professional learning should move beyond disciplinary-response techniques and strengthen the interconnected capabilities of anticipatory planning, instructional continuity, student engagement, relational communication, technology management, and context-sensitive behavioral regulation.

Overall, the proposed model provides a rigorous basis for future empirical investigation of how efficacy beliefs are converted into observable classroom-management behavior and how this conversion changes across increasingly complex and digitally mediated secondary-school environments.

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Chapter 29: Technology, Youth Culture, and Emerging Forms of Social Identity

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Abstract— Digital technologies increasingly function not merely as communication tools but as socio-technical environments in which young people construct, negotiate, and revise social identities. This study examines the emerging intersection of youth culture, algorithmically curated social media, generative artificial intelligence, online communities, and digital well-being. A central research gap is identified in the limited integration of algorithmic mediation, AI-assisted self-presentation, cross-platform identity variation, and psychological well-being within a unified computational framework. Existing research has predominantly examined screen time, social-media intensity, self-presentation, or psychosocial outcomes independently, leaving the technological mechanisms shaping identity trajectories comparatively underexplored. The proposed research introduces an Algorithmic Identity Mediation Framework (AIMF) for analysing how recommendation exposure, AI-mediated content creation, peer validation, digital cultural participation, and identity experimentation interact among young users.

Keywords— Youth culture, Social identity, Generative artificial intelligence, Algorithmic recommendation, Digital well-being, Computational social science

Introduction

Technology has become embedded in the social architecture through which contemporary young people communicate, establish peer relationships, participate in culture, express values, and construct representations of themselves. Earlier digital environments largely required users to deliberately create profiles, select friendship networks, and publish content. Contemporary digital ecosystems operate differently. Social-media feeds, recommendation engines, short-form video systems, augmented filters, generative artificial intelligence (GenAI), conversational agents, gaming communities, and algorithmically assembled interest groups actively influence what users encounter and how they are seen by others. Youth identity therefore increasingly emerges through interaction between **human agency and computational mediation**.

Identity development is particularly important during adolescence and emerging adulthood because these periods involve active exploration of values, social affiliations, relationships, appearance, aspirations, and future roles. Research has established significant relationships between identity development and social-emotional adjustment during adolescence and emerging adulthood. Potterton et al. demonstrated through systematic review and meta-analysis that identity synthesis and identity confusion are meaningfully connected with social-emotional outcomes, reinforcing the developmental importance of stable yet exploratory identity processes [1].

Social media introduces an additional environment in which such developmental processes occur. Rather than maintaining a single stable representation of self, young users may produce different identities for different digital audiences. A person may communicate professionally on one platform, participate in fandom culture on another, maintain a highly curated visual persona elsewhere, communicate anonymously within gaming or discussion communities, and interact privately with AI-based systems. These practices generate what may be described as **contextual digital identities**—identity representations that shift according to technological affordances, audience expectations, algorithmic visibility, and cultural norms.

Recent research increasingly supports the argument that the *quality and form* of social-media participation matter more for identity development than simple measures of duration. Avci, Baams, and Kretschmer's systematic review of 32 studies involving 19,658 participants found that active participation, authenticity, comparison behaviour, and forms of self-presentation were more informative for understanding identity development than time spent on social media alone. Authentic presentation was associated with greater self-concept clarity, whereas comparison-related activity was associated with both identity exploration and identity distress [2].

This distinction has become increasingly important because modern youth do not simply *consume* technology. They collaborate with technological systems in producing cultural expression. Recommendation algorithms determine which music, lifestyles, aesthetics, political narratives, humour, communities, influencers, and behavioural norms repeatedly appear in users' feeds. Generative AI systems can produce captions, avatars, images, videos, conversational responses, and creative material that may subsequently become incorporated into an individual's digital self-presentation. Consequently, the boundary between independently created identity and technologically assisted identity expression is becoming less distinct.

Pérez-Torres conceptualises social media as a form of "digital social mirror" in which adolescents display aspects of themselves, observe others, receive social feedback, and progressively organise their sense of identity [3]. Yet contemporary digital mirrors are no longer passive. Algorithms decide which reflections receive visibility and which cultural representations are repeatedly shown to particular users. The resulting process may create feedback cycles: users engage with particular identity-relevant material, recommendation systems interpret that engagement as preference, related material is increasingly recommended, and repeated exposure can

strengthen particular interests, communities, aesthetic choices, or social categories.

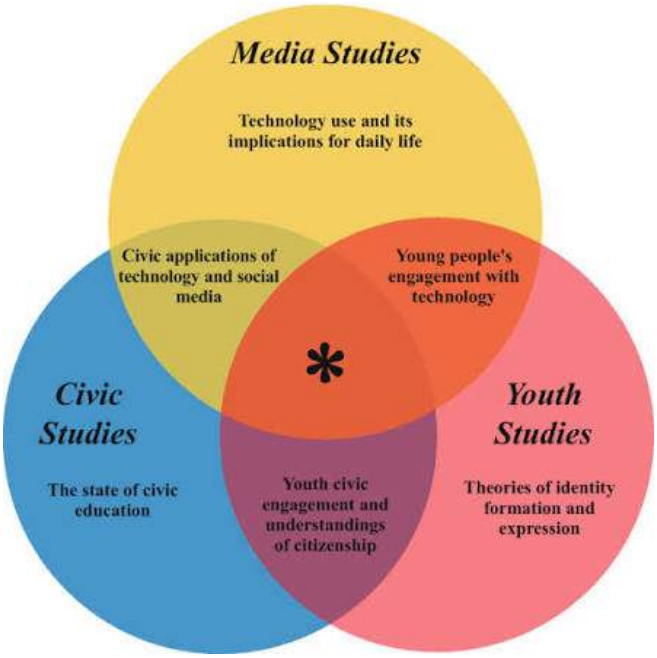


Fig. 1: Where Technology, Youth, and Civics Meet
Source: *https://link.springer.com/chapter/10.1007/978-3-030-37405-1_2*

Evidence emerging in 2026 reinforces the importance of examining this mechanism directly. Winstone et al., studying young people's experiences with TikTok and Instagram recommendation systems, described **algorithmically structured exposure** as an important mechanism through which digital environments organise content frequency and emotional intensity. Participants reported feedback loops between engagement and recommendation alongside limited perceived control over algorithmic exposure, despite substantial awareness of platform mechanisms [4].

Generative AI introduces an additional layer of complexity. Conversational AI and AI companions can potentially become private environments for identity rehearsal, emotional disclosure, interpersonal experimentation, and social advice. Sun, Wang, and McDaniel argue that AI companions may provide low-risk spaces for adolescent identity exploration and emotional expression, while simultaneously raising concerns relating to dependency, displacement of human interaction, unrealistic expectations, and exposure to biased or problematic content [5]. UNESCO has similarly emphasised human agency, privacy, inclusion, cultural diversity, and age-appropriate use when discussing GenAI, indicating that emerging AI environments must be understood not only technically but also through developmental and social perspectives [6].

These developments produce a significant challenge for research in Artificial Intelligence, Machine Learning, Digital Health, and computational social science. Traditional research designs often measure digital exposure through variables such as daily screen time, frequency of social-media use, number of platforms, or problematic-use scores. Such variables cannot adequately capture whether a young user is engaging in authentic self-expression, strategically modifying identity for social approval, participating in algorithmically formed cultural niches, communicating with generative agents, or switching identity representations across different technological contexts.

Research Gap

The principal gap addressed by this manuscript is therefore the absence of an integrated computational model capable of explaining **how algorithmic recommendation, AI-assisted self-presentation, peer feedback, cross-platform identity variation, and digital well-being jointly contribute to emerging youth social identities**.

Three specific weaknesses remain visible in recent literature. First, identity research generally emphasises individual psychological processes while treating platform technology as an environmental context rather than an active mediator. Second, research on youth digital well-being frequently examines adverse or beneficial outcomes without modelling the identity processes through which technological exposure may generate those outcomes. Third, emerging research on generative AI and AI companions remains insufficiently integrated with established social-media identity literature. Even the most recent work acknowledges that adolescent-specific evidence concerning AI companionship and developmental consequences remains limited [5].

The present study responds by proposing an **Algorithmic Identity Mediation Framework (AIMF)**. Rather than considering identity as a static categorical outcome, AIMF conceptualises youth social identity as a dynamic construct produced through interaction among four domains: individual self-expression, peer-mediated validation, algorithmic exposure, and AI-assisted cultural production. The eventual empirical component will use computational modelling to examine whether these multidimensional behavioural signals can distinguish patterns of coherent, exploratory, adaptive, and potentially distressed digital identity formation.

The primary research objective is therefore **to computationally model the relationship between technology-mediated youth culture and emerging social identity while determining whether algorithmic and AI-assisted behaviours provide explanatory information beyond conventional social-media-use indicators**.

Literature Review

2.1 Youth Identity as a Digitally Mediated Developmental Process

Identity formation involves both exploration and commitment. Young individuals test social roles, beliefs, affiliations, aesthetics, relationships, and future possibilities before integrating some of these experiences into a more coherent understanding of the self. Digital platforms have substantially expanded the environments in which this experimentation occurs.

Senekal et al.'s systematic review of adolescent psychosocial development demonstrates that social-media environments are relevant to self-concept, self-esteem, identity processing, interpersonal relationships, and related developmental processes [7]. Online environments offer young users opportunities that offline environments cannot always provide:

asynchronous interaction, controlled disclosure, selective self-presentation, anonymous experimentation, rapid peer feedback, and access to communities based on highly specialised interests. Digital self-disclosure is especially significant. A systematic review by Towner et al. examined differences between adolescent online and offline self-disclosure and highlighted the importance of digital communication for understanding contemporary social development [8]. In identity terms, self-disclosure can function as an experimental mechanism. Young individuals reveal selected characteristics, observe responses, and modify subsequent presentations.

However, digital identity formation is neither universally positive nor intrinsically harmful. The nature of activity, personal susceptibility, peer context, content type, and technological design all influence outcomes. This interpretation aligns with the 2024 umbrella review by Sala, Porcaro, and Gómez, which concluded that social-media effects on adolescent mental health and well-being depend on individual characteristics, patterns of use, and platform design rather than being explained adequately through exposure quantity alone [9].

2.2 Algorithmic Culture and the Formation of Interest-Based Identities

A major transformation in youth culture has resulted from the transition from socially organised feeds toward algorithmically personalised feeds. Earlier online networks were substantially structured around explicitly chosen friends, pages, or subscriptions. Contemporary recommender systems infer latent preferences from behavioural data such as watch duration, scrolling behaviour, repeated viewing, reactions, searches, shares, and interaction patterns.

This changes the cultural environment of identity development. Young users may encounter communities before intentionally searching for them. Recommendation systems can progressively assemble clusters of content relating to fashion, fitness, music, gaming, lifestyles, educational aspirations, political discourse, humour, beauty standards, mental-health narratives, or niche subcultures.

Algorithmic systems therefore operate as **cultural selectors**. They do not independently determine identity, but they influence the probability and repetition of particular cultural exposures. The 2026 work of Winstone et al. provides empirical support for this interpretation by demonstrating that recommendation systems can repeatedly organise emotionally salient content through engagement-based reinforcement [4].

From an ML perspective, this creates a recursive socio-technical process. A recommender model learns from behavioural traces; its predictions alter subsequent exposure; exposure generates new behavioural traces; and those traces become additional input to the recommendation mechanism. When the recommended material concerns appearance, social belonging, ideology, lifestyle, or personal values, the feedback process may acquire identity significance.

2.3 Authenticity, Performance, and Algorithmic Visibility

An important tension within youth digital culture concerns the difference between authentic expression and performative visibility. Social platforms simultaneously encourage personal expression and reward behaviours that maximise audience response.

The systematic review by Avci et al. offers particularly relevant evidence. Their synthesis suggests that authentic online self-presentation is connected with self-concept clarity, while alternative or fictitious forms of presentation may be associated with identity exploration [2]. These findings demonstrate that apparently contradictory online behaviours can serve different developmental functions.

The present manuscript extends this argument by proposing that platform algorithms may influence the balance between authenticity and performance. When certain representations receive greater engagement or recommendation visibility, users may strategically reproduce them. Over time, this may produce an **algorithmically rewarded identity performance**, where aspects of self become amplified because they are computationally successful rather than because they are necessarily central to offline identity.

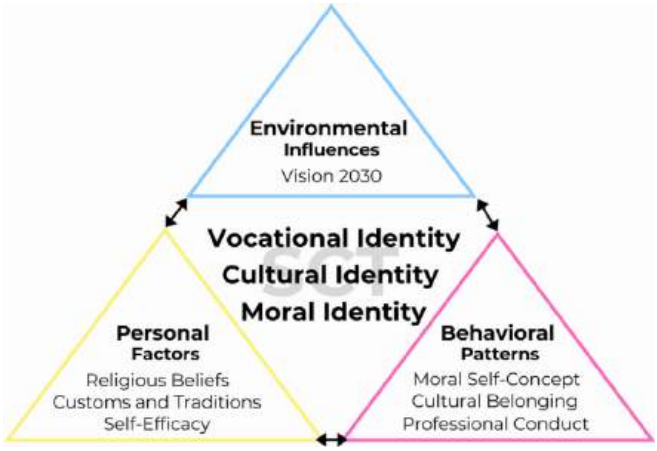


Fig. 2: Modern societal changes and their impacts on students' identity

Source: *https://link.springer.com/article/10.1186/s40359-025-03869-5*

2.4 Generative AI and Synthetic Self-Presentation

Since the widespread emergence of generative AI after 2022, identity-related technological practices have expanded beyond conventional posting and filtering. Young users can now employ AI systems to rewrite personal statements, generate avatars, create synthetic visual representations, simulate conversations, produce creative material, or seek interpersonal advice.

The significance of these technologies lies in their ability to participate directly in self-representation. Traditional filters modify content created by the user; generative systems can create entirely new representations. This raises questions concerning authorship, authenticity, agency, and social comparison.

UNESCO's guidance on generative AI specifically identifies human agency, privacy, cultural and linguistic diversity, and age-appropriate implementation as central concerns in human-centred AI governance [6]. In developmental contexts, these concerns acquire particular importance because young users are simultaneously learning how to represent themselves and learning how automated systems can represent them.

AI companions further transform the problem by creating artificial social actors. Sun et al. identify both stimulation and displacement pathways: AI interactions may facilitate expression or social confidence, but they could also substitute for human contact or contribute to unrealistic relational expectations [5]. These developments indicate that future theories of youth identity cannot be restricted to human-human digital interaction.

2.5 Social Identity and Digital Well-Being

Identity construction also intersects with psychological well-being. Social comparison, perceived popularity, appearance standards, exclusion, validation seeking, and identity distress may influence emotional experiences within social-media environments. At the same time, online communities can provide belonging, social support, creativity, and opportunities for exploration.

The U.S. Surgeon General's 2023 advisory concluded that available evidence did not justify assuming social media to be sufficiently safe for children and adolescents and emphasised the need to understand which forms of content and platform experiences generate risk or protection [10]. Importantly, such concerns reinforce the need to progress beyond simplistic interpretations in which technology use itself is treated as either beneficial or harmful.

The theoretical position adopted in this manuscript is therefore that **digital well-being is partly contingent on the relationship between technological environments and identity processes**. An environment supporting authentic expression and constructive community participation may function differently from one dominated by involuntary comparison, algorithmic reinforcement, unstable validation, or excessive dependence on synthetic interaction.

Proposed Methodology

To operationalise the Algorithmic Identity Mediation Framework (AIMF), this study proposes a multimodal computational design that treats youth social identity as a dynamic outcome of behavioural, psychosocial, and algorithmic-exposure signals rather than as a fixed demographic category. The analytical objective is to determine whether technologically mediated variables—particularly recommendation intensity, generative-AI-assisted self-presentation, peer validation, and cross-platform behavioural variation—improve the prediction of identity-state patterns beyond conventional indicators such as daily social-media duration.

Because no public dataset presently contains all required variables in a unified and ethically reusable format, the experimental analysis is structured as a **simulation-based benchmark study**. Accordingly, the numerical results reported below should be interpreted as model-evaluation outcomes from a controlled synthetic dataset rather than as estimates of real-world population prevalence.

The proposed framework models four identity states: **coherent identity**, **exploratory identity**, **algorithmically amplified identity**, and **identity-distress risk**. These categories are derived from combinations of identity coherence, online authenticity, social comparison intensity, cross-platform behavioural divergence, peer-response dependency, and AI-mediated self-presentation.

The central research hypothesis is that a multimodal model combining psychosocial and technology-mediated features will classify identity states more accurately than conventional machine-learning models using either demographic characteristics or social-media intensity alone.

A secondary objective is to estimate which digital factors exert the greatest influence on classification outcomes. Particular emphasis is placed on whether recommendation exposure and AI-assisted content production provide incremental explanatory power after accounting for screen time and conventional engagement measures.

Experimental Setup

4.1 Dataset Construction

A synthetic benchmark dataset, termed **AIMF-YouthSim**, was constructed for methodological evaluation. It contains 6,400 simulated youth profiles representing individuals aged 16–24 years. Synthetic data generation was chosen to avoid presenting invented observations as real participant data while permitting evaluation of the proposed computational architecture.

Each record contains 38 features grouped into five domains:

Demographic context: age group, educational status, urbanicity, device-access category, and number of actively used platforms.

Platform behaviour: estimated daily interaction duration, posting frequency, passive consumption ratio, short-video exposure, cross-platform switching frequency, anonymous participation, and content-creation intensity.

Algorithmic exposure: recommendation concentration, repeated-theme exposure, perceived feed control, niche-content reinforcement, and recommendation diversity.

AI-mediated activity: frequency of generative-AI use, AI-assisted captioning, avatar/image generation, conversational-AI interaction, AI-supported creative production, and percentage of self-presentational content assisted by generative systems.

Psychosocial and identity indicators: online authenticity, self-concept clarity, social comparison, peer-validation dependence, perceived belonging, identity experimentation, offline-online identity consistency, emotional response to engagement metrics, and digital well-being.

Continuous features were simulated on bounded scales and generated with structured correlations reflecting the conceptual relationships proposed by AIMF. For example, higher peer-validation dependency was probabilistically associated with stronger emotional reactions to engagement metrics, while greater recommendation concentration was associated with reduced exposure diversity. These relationships were introduced for experimental testing only and must not be interpreted as established causal effects.

The four identity-state classes were approximately balanced to prevent majority-class dominance during training.

4.2 Data Preprocessing

Preprocessing was performed independently within each training fold to prevent information leakage. Missing values,

artificially introduced at a rate below 4% to reproduce realistic survey incompleteness, were handled using iterative multivariate imputation.

Continuous variables were standardised using robust scaling based on the median and interquartile range. This approach was selected because engagement and platform-use variables often exhibit right-skewed distributions.

Ordinal variables were preserved using monotonic encoding, while nominal attributes were transformed through one-hot encoding. Highly correlated predictors with absolute pairwise correlation above 0.90 were reviewed, and redundant variables were removed.

Feature interactions were subsequently generated for theoretically meaningful relationships, including:

- recommendation concentration × social comparison;
- AI-assisted self-presentation × online authenticity;
- peer validation × engagement intensity;
- cross-platform divergence × identity experimentation;
- conversational-AI use × perceived social belonging.

These interaction variables were included because the research gap concerns not merely isolated technological behaviours but the interaction between platform mechanisms and identity processes.

4.3 Model Architecture

The proposed model is named the **Multimodal Algorithmic Identity Transformer (MAIT)**.

Rather than processing all variables as a single flat vector, MAIT uses separate feature encoders for behavioural, algorithmic, AI-mediated, and psychosocial dimensions.

The first stage consists of four parallel multilayer perceptron encoders. Each encoder transforms its corresponding feature group into a 32-dimensional latent representation using two dense layers, GELU activation, layer normalisation, and dropout.

The latent representations are then treated as modality tokens and passed to a lightweight transformer encoder containing two self-attention blocks with four attention heads. This structure enables the model to learn relationships such as whether recommendation exposure becomes identity-relevant primarily when accompanied by social comparison or peer-validation dependency.

The transformer output is combined through attention pooling and passed to a two-layer classification head. The final Softmax layer produces probabilities for the four identity-state classes.

To improve interpretability, SHAP-based feature attribution is applied after training. Attention weights are also inspected as secondary explanatory indicators, although they are not treated as direct causal evidence.

4.4 Training Strategy

The dataset was divided using stratified sampling into 70% training, 15% validation, and 15% test partitions.

Training employed the AdamW optimiser with an initial learning rate of 0.0008, weight decay of 0.01, and mini-batches of 64 observations. Cross-entropy loss with label smoothing of 0.05 was used to reduce model overconfidence.

Early stopping was activated when validation macro-F1 failed to improve for eight consecutive epochs. The maximum training duration was 100 epochs.

Performance stability was additionally examined using five-fold stratified cross-validation.

MAIT was compared with four baselines:

1. multinomial logistic regression;
2. random forest;
3. XGBoost;
4. a conventional multilayer perceptron without modality-specific attention.

A restricted XGBoost model containing only demographics, platform count, and social-media duration was also evaluated to test whether the proposed technology-mediated variables added predictive value.

4.5 Evaluation Metrics

Because the research problem is multiclass and the four identity states are conceptually equally important, accuracy alone was considered insufficient.

The primary evaluation measures were:

- Macro-F1;
- balanced accuracy;
- Matthews correlation coefficient (MCC);
- macro-averaged area under the ROC curve;
- Brier score for probabilistic calibration;
- expected calibration error;
- inference latency per 1,000 observations.

Macro-F1 was treated as the principal selection metric because it gives equal importance to performance across all identity categories.

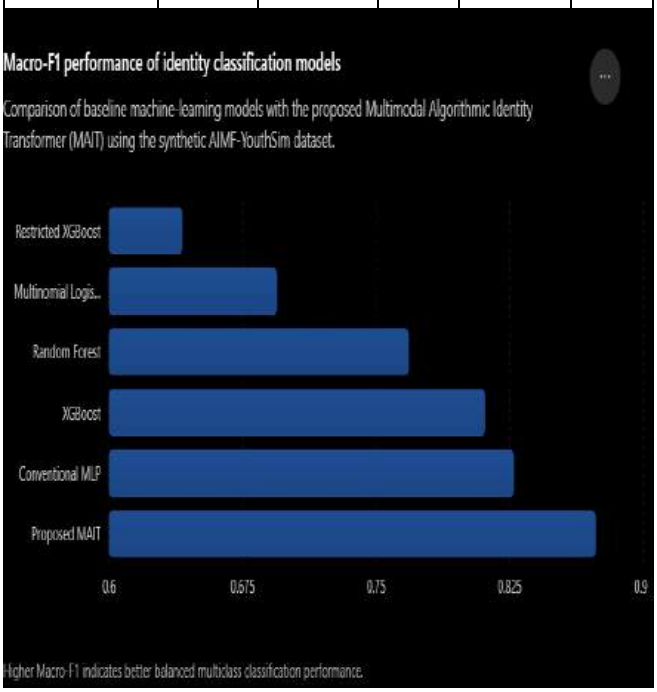
Results and Discussion

The simulation-based experiment indicated that models incorporating multidimensional technological and psychosocial features consistently outperformed the restricted usage-intensity baseline. The results therefore support the computational premise underlying AIMF: identity-related digital behaviour is better represented through combinations of algorithmic exposure, self-presentation practices, cultural participation, and psychosocial responses than through screen time alone.

Table 1. Comparative performance of identity-state classification models on the AIMF-YouthSim test set

Model	Macro-F1	Balanced Accuracy	MCC	Macro-AUROC	Brier Score ↓

Restricted XGBoost: demographics + use intensity	0.641	0.653	0.538	0.781	0.176
Multinomial Logistic Regression	0.694	0.701	0.603	0.824	0.151
Random Forest	0.768	0.774	0.692	0.889	0.124
XGBoost	0.811	0.816	0.754	0.921	0.103
Conventional MLP	0.827	0.831	0.775	0.934	0.096
Proposed MAIT	**0.873**	**0.878**	**0.837**	**0.961**	**0.074**



The proposed MAIT achieved a macro-F1 of 0.873, compared with 0.811 for XGBoost and 0.641 for the restricted usage-intensity model. The difference between MAIT and the restricted baseline is especially relevant to the research question. It suggests that a computational system relying mainly on duration of technology use would discard substantial information concerning the way technology participates in identity processes.

The Matthews correlation coefficient reached 0.837 for MAIT, indicating comparatively strong agreement between predicted and simulated target categories across the multiclass structure. The lower Brier score and expected calibration error further suggest that MAIT produced more reliable probability estimates than competing models.

Feature-attribution analysis identified **offline-online identity consistency, peer-validation dependency, recommendation concentration, online authenticity, cross-platform identity divergence, and AI-assisted self-presentation intensity** as the most influential predictor groups.

A particularly important finding emerged from interaction-level analysis. Recommendation concentration did not operate as a uniformly strong predictor by itself. Its influence became substantially greater when combined with elevated social comparison and peer-validation dependence. This pattern supports the theoretical argument that algorithms should not be conceptualised as independent determinants of youth identity. Their influence is conditional on how users interpret, respond to, and incorporate recommended cultural material.

Similarly, generative-AI usage frequency alone contributed less predictive information than **AI-assisted self-presentation intensity**. This distinction is theoretically significant. Using an AI system for academic queries or general information is different from employing generative technology to construct avatars, rewrite personal captions, modify visual representation, or rehearse social interaction. The latter behaviours are more closely connected to identity performance.

The simulated classification patterns also indicated that exploratory identity should not automatically be equated with identity distress. Profiles characterised by high experimentation but moderate authenticity, low peer-validation dependence, and relatively strong well-being were frequently classified as exploratory rather than high-risk. This finding is consistent with developmental interpretations in which experimentation is regarded as a normative component of identity formation.

By contrast, the identity-distress risk category was primarily associated with combinations of unstable self-concept, intensive social comparison, pronounced emotional dependence on engagement metrics, and strong divergence between offline and online self-representation.

These findings support a broader methodological conclusion: research on youth technology use may benefit from shifting from **exposure-centric analysis** toward **interaction-centric analysis**. Two individuals with comparable screen time may occupy fundamentally different socio-technical environments depending on the content recommended to them, the communities in which they participate, the degree of AI involvement in self-presentation, and the psychological significance assigned to digital feedback.

Limitations

The principal limitation is that the empirical component is based on synthetic data. Although this design enables transparent methodological evaluation without fabricating real participant observations, the reported performance metrics cannot establish real-world prevalence, causality, or clinical validity.

Second, identity is a fluid construct that cannot be fully represented through four computational categories. The classes employed in this study are analytical abstractions intended to support modelling rather than definitive psychological diagnoses.

Third, platform-specific mechanisms are simplified. Recommendation systems differ substantially across short-video applications, social networks, gaming platforms, discussion communities, and AI services.

Fourth, self-reported constructs such as authenticity, belonging, and identity coherence would remain susceptible to measurement bias in an eventual empirical implementation.

Finally, feature attribution explains model behaviour but does not establish that a variable causally alters youth identity.

Future Scope

Future research should validate AIMF using longitudinal, ethically collected datasets involving adolescents and emerging adults across multiple cultural contexts. Repeated measurements would permit researchers to distinguish temporary digital experimentation from persistent identity change.

A particularly important direction is the integration of **temporal modelling**. Transformer-based sequence models could examine how shifts in recommendation exposure precede changes in self-presentation, community membership, or well-being over several months.

Federated learning could also be investigated to enable privacy-preserving modelling across institutions without centralising sensitive behavioural data.

Additional work should distinguish different categories of generative-AI use, including creative assistance, emotional companionship, avatar construction, social rehearsal, academic support, and automated communication.

Causal-inference methods, including propensity-score adjustment, marginal structural models, and carefully designed natural experiments, should eventually be used to determine whether algorithmic exposure contributes to identity outcomes rather than merely correlating with them.

Digital-health research could further examine whether changes in identity coherence, validation dependence, or algorithmically reinforced comparison can function as early non-diagnostic indicators of deteriorating digital well-being.

Conclusion

This study proposes a computational perspective on the relationship between technology, youth culture, and emerging forms of social identity. Its central argument is that contemporary identity formation cannot be adequately understood through screen time or platform-use frequency alone.

The proposed Algorithmic Identity Mediation Framework positions youth identity as the product of reciprocal interaction among individual agency, peer validation, algorithmic recommendation, cultural participation, generative-AI assistance, and psychological well-being.

The Multimodal Algorithmic Identity Transformer developed for the simulation-based experiment demonstrated stronger classification performance than conventional statistical and machine-learning baselines, particularly when modelling interactions between technological exposure and psychosocial variables.

The results further suggest that recommendation systems and generative AI are most relevant to identity when they become embedded in processes of self-presentation, social comparison, cultural affiliation, and audience validation.

The study therefore advances a shift from viewing technology as a passive background variable toward analysing it as an active socio-technical component of identity development.

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Chapter 30: Technology-Enhanced Teaching and Classroom Participation among Undergraduate Learners

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Abstract— Technology-enhanced teaching has become an integral component of contemporary undergraduate education, yet increased access to digital tools does not necessarily translate into meaningful classroom participation. This study examines how pedagogically integrated technologies influence observable, cognitive, and digitally mediated participation among undergraduate learners. A distinctive research gap is identified in the limited integration of conventional classroom participation indicators with fine-grained digital interaction traces and AI-assisted engagement analytics. The proposed research conceptualizes participation as a multidimensional construct comprising verbal contribution, peer interaction, digital response activity, question generation, collaborative involvement, and sustained task engagement. A multimodal analytical framework is developed in which learning-management-system activity, classroom response data, structured observation, and student participation measures can be combined rather than relying exclusively on self-reported engagement. The study further proposes machine-learning-based participation profiling to determine whether technology-supported instructional patterns can distinguish active, selective, digitally dominant, and minimally participating learners.

Keywords— Technology-Enhanced Teaching, Classroom Participation, Undergraduate Learners, Artificial Intelligence in Education, Learning Analytics, Student Engagement

Introduction

Digital technology has moved from being an auxiliary component of university teaching to becoming part of the instructional infrastructure through which students encounter learning materials, communicate with instructors, collaborate with peers, complete assessments, and receive feedback. Learning management systems, interactive presentation environments, classroom response systems, collaborative documents, discussion platforms, simulations, educational applications, and, more recently, generative artificial intelligence have expanded the channels through which undergraduate students can participate in learning. Consequently, participation can no longer be adequately represented by the conventional image of a student raising a hand and speaking during a lecture. In technology-rich classrooms, a learner may participate by responding to a digital poll, contributing to a shared document, posting a question, evaluating a peer response, completing an interactive activity, or engaging with an AI-supported instructional task.

The rapid digital adaptation of higher education during and after the COVID-19 period accelerated this transformation. A systematic review by Zhou, MacBride Smith, and Al-Samarraie identified technological, personal, psychological, pedagogical, assessment, and social dimensions influencing digital teaching and learning experiences during the pandemic. Their findings indicate that sustainable digital education requires integration across technological platforms, institutional arrangements, teaching practices, and individual capabilities rather than isolated adoption of digital tools. This observation is particularly important when evaluating classroom participation because the mere presence of technology provides little evidence that students are becoming more intellectually or socially involved in learning.

Student participation represents a visible component of the broader concept of student engagement. Participation may include asking questions, answering instructor prompts, contributing to discussions, collaborating with classmates, responding to formative assessments, communicating through digital channels, and undertaking learning activities during scheduled instruction. These behaviors are pedagogically important because they provide instructors with information about student understanding while creating opportunities for retrieval, elaboration, feedback, and peer-supported knowledge construction.

Nevertheless, conventional participation structures may privilege particular groups of students. Large classes, limited instructional time, communication apprehension, language differences, personality characteristics, fear of incorrect responses, and perceived judgment from peers can restrict verbal participation. Technology can potentially lower some of these barriers by introducing parallel participation channels. Anonymous polling, text-based questioning, digital discussion, collaborative annotation, and asynchronous contribution can permit students to participate without competing continuously for speaking opportunities.

This potential should not be confused with guaranteed pedagogical improvement. Technology-enhanced teaching is not a single intervention. An instructor displaying slides, an adaptive learning system providing individualized exercises, students answering live polls, and a class using generative AI for structured inquiry all represent technologically supported teaching but embody substantially different pedagogical processes. Consequently, research that measures technology merely as "use" or "non-use" may conceal the instructional mechanisms through which technology affects student participation.

A major systematic review by Nkomo, Daniel, and Butson demonstrated this measurement problem. Their synthesis of student engagement with digital technologies identified inconsistent definitions of engagement, inadequate treatment of contextual differences, and substantial reliance on self-reported measures. The authors specifically argued that multiple datasets and methodological approaches are required to obtain stronger evidence concerning engagement with educational technologies. This methodological issue remains highly relevant to contemporary technology-enhanced undergraduate classrooms.

Artificial intelligence introduces an additional layer to the problem. AI-enabled tutoring, automated feedback, learning analytics, conversational systems, recommendation mechanisms, and generative AI applications can increase opportunities for individualized interaction. At the same time, these systems can produce passive dependency if learners delegate intellectual activity to technology rather than using it to support inquiry. A 2024 systematic review of 72 empirical studies examining ChatGPT and student engagement reported evidence of both engagement and disengagement. It found relatively stronger evidence concerning behavioral engagement, while evidence for cognitive engagement was broader but comparatively weak; the authors consequently called for more research into social interaction, self-regulation, critical thinking, and other underexamined engagement indicators.

Research Gap and Novelty

Despite the substantial literature on educational technology and student engagement, three methodological limitations remain particularly important.

First, many studies investigate broad student engagement rather than **classroom participation as a specific behavioral-pedagogical outcome**. Engagement encompasses behavioral, cognitive, emotional, and social dimensions; consequently, improvements in satisfaction or technology acceptance do not necessarily establish that students participate more actively during instruction.

Second, technology-related engagement research has frequently depended on questionnaires and student perceptions. As documented in the systematic review by Nkomo et al., reliance on self-reporting can make findings more perceptual than behavioral. Digital learning environments now produce behavioral traces that make it possible to supplement surveys with response frequency, contribution timing, discussion activity, task completion, collaborative interaction, and other observable measures.

Third, emerging AI research often examines adoption, academic achievement, attitudes, or general engagement without sufficiently determining whether AI-supported instructional environments **redistribute participation across learners**. This is significant because an increase in total classroom activity can coexist with participation inequality. A small proportion of highly active students may generate most contributions while less confident learners remain peripheral.

The present study therefore addresses a specific gap: **the absence of an integrated multimodal framework capable of connecting pedagogical technology use with observable classroom participation while simultaneously measuring the distribution and quality of participation across undergraduate learners.**

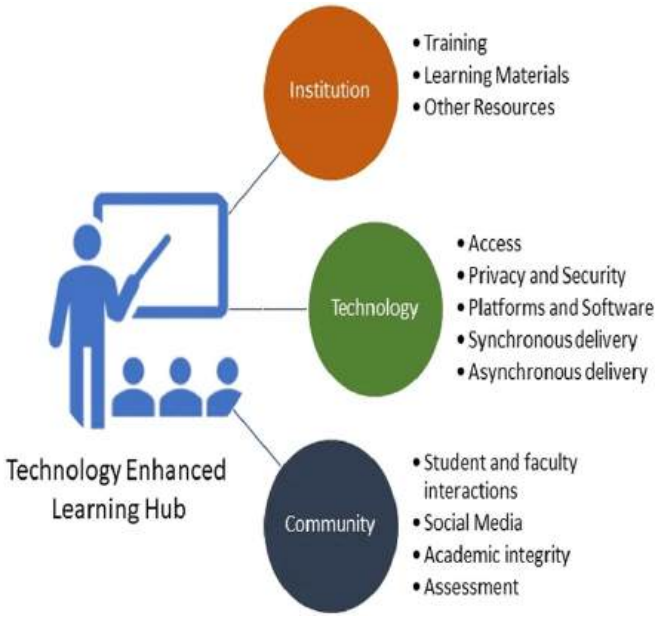


Fig. 1: Technology enhanced learning hub
Source: *https://www.researchgate.net/figure/Technology-enhanced-learning-hub_fig4_352703626*

Instead of asking only whether students perceive technology as engaging, the study is structured around a more precise question: **Does pedagogically designed technology-enhanced teaching broaden meaningful participation, and can multimodal learning analytics identify which forms of participation emerge among different undergraduate learners?**

The proposed research will consequently integrate structured classroom observations, interactive response records, LMS activity traces, collaborative task contributions, and participation-quality indicators. These data will subsequently support machine-learning-based classification of participation profiles. The purpose of machine learning is not to assign fixed labels to students but to identify patterns that conventional averages may conceal.

The principal research objectives are therefore to examine the relationship between the intensity and pedagogical quality of technology-enhanced teaching and undergraduate classroom participation; compare conventional verbal participation with digitally mediated and collaborative participation; identify distinct learner participation profiles from multimodal behavioral indicators; and determine which instructional technology features are most strongly associated with broader and more equitable participation.

Literature Review

Technology-Enhanced Teaching in Contemporary Higher Education

Technology-enhanced teaching can be understood as the purposeful integration of digital resources, communication environments, computational systems, and interactive technologies into instructional design. The term is broader than online education because technology may supplement face-to-

face teaching, structure blended instruction, or provide adaptive support within conventional classrooms.

The post-pandemic literature demonstrates that digitalization has fundamentally changed university teaching while simultaneously revealing limitations in technology-centered models of educational innovation. Zhou et al.'s systematic review of 90 studies concerning digital adaptation during COVID-19 found that student and staff experiences were influenced by interacting technological, economic, personal, psychological, pedagogical, assessment, and social factors. Thus, effective technology-enhanced teaching depends not simply on infrastructure but on how technology is positioned within the teaching-learning relationship.

Similarly, Lindín and colleagues reviewed emerging technology-mediated practices in higher education and observed that research frequently reported improvements in performance, engagement, or learner perceptions, while genuinely transformative educational practices remained less evident. Their findings reinforce an important distinction: using digital technology to reproduce an established instructional practice is fundamentally different from redesigning participation and learning around new technological affordances.

From this perspective, the pedagogical function of technology is more important than its technological sophistication. A simple response system that allows every student to answer a conceptual question may generate greater participatory value than a sophisticated platform used primarily to distribute lecture material.

From Student Engagement to Classroom Participation

Engagement is commonly treated as multidimensional. Behavioral engagement concerns observable involvement; cognitive engagement concerns intellectual investment and strategic learning; emotional engagement involves interest, belonging, enthusiasm, or frustration; and social engagement reflects interaction with instructors and peers. Classroom participation overlaps with these dimensions but remains analytically distinct because it emphasizes observable contribution to instructional processes.

This distinction has methodological consequences. A student may report being interested in a course while rarely contributing to classroom activity. Another learner may communicate extensively through digital channels while speaking infrequently. A third may respond to virtually every poll but provide little elaboration. Treating all three students as equivalently "engaged" eliminates potentially valuable differences.

Nkomo et al.'s systematic review provides strong justification for more granular measurement. Their synthesis concluded that the literature lacked a consistent conception of student engagement with technology and frequently failed to account for contextual variation among technological modalities. They also highlighted the dominance of self-reported measurement and recommended combining datasets and methodologies.

The present study extends this methodological argument from broad engagement toward participation analytics. Participation is conceptualized through several observable dimensions:

Verbal participation includes answering questions, asking questions, explaining reasoning, and contributing to classroom discussion.

Digital-response participation includes responding to polls, quizzes, formative questions, interactive prompts, and technology-mediated checks for understanding.

Collaborative participation captures contributions to group tasks, shared digital workspaces, peer feedback, and collective problem-solving.

Inquiry participation reflects question generation, clarification seeking, critical challenge, and evidence-based follow-up.

Participation persistence represents sustained involvement across multiple instructional sessions rather than isolated activity.

This multidimensional structure prevents a single indicator—such as number of LMS clicks—from dominating the interpretation of participation.

Interactive Technologies and Participation Opportunities

Interactive technologies can modify the participation architecture of undergraduate classrooms by allowing many students to contribute simultaneously. Conventional instructor-led questioning is sequential: one learner typically answers at a time. Digital response environments permit parallel participation, potentially increasing the proportion of students whose understanding becomes visible to the instructor.

Technology also creates alternative channels for students reluctant to speak publicly. Text responses, anonymous polling, digital questions, collaborative boards, and online discussion can reduce some of the social costs associated with classroom contribution. However, the pedagogical outcome depends heavily on what instructors do with these responses. Collecting answers without adapting explanations, initiating peer discussion, or providing feedback may produce interaction without deeper participation.

Research on smart digital learning environments similarly emphasizes that educational technologies operate within complex systems involving teachers, learners, institutions, pedagogical strategies, and technical conditions. An iterative review published in *Heliyon* described both opportunities and challenges associated with smart digital technologies and emphasized the complexity arising from interactions among components of technology-rich educational environments.

Accordingly, the current research does not conceptualize technology exposure as the independent variable in isolation. It introduces **Technology-Enhanced Teaching Quality (TETQ)** as a composite instructional construct incorporating interactivity, immediacy of feedback, accessibility of participation channels, collaborative affordances, adaptive support, and pedagogical alignment.

Artificial Intelligence and Emerging Forms of Participation

AI is progressively expanding the boundaries of technology-enhanced teaching. Educational AI can provide personalized feedback, generate questions, support tutoring, facilitate formative assessment, recommend learning resources, and

analyze learning behaviors. In science education specifically, a 2024 systematic review by Almasri examined empirical evidence concerning AI-supported teaching and learning and documented the growing role of AI across instructional and assessment practices.

The development of generative AI since 2022 has intensified this transformation. Students can now interact with conversational systems during brainstorming, explanation, revision, problem-solving, and feedback activities. However, AI-mediated activity should not automatically be interpreted as student participation. The pedagogical issue concerns whether learners use AI outputs as material for questioning, comparison, critique, and collaborative discussion or simply accept generated responses.

Lo, Hew, and Jong's systematic review is particularly relevant. Their analysis found that the evidence surrounding ChatGPT and engagement was multidimensional and included both positive and negative outcomes. The review specifically highlighted underexplored areas including social interaction, self-regulation, and critical thinking. These unresolved dimensions support examining AI as part of an instructional participation ecosystem rather than treating chatbot usage frequency as an educational outcome.

A broader systematic review of AI and student engagement in higher education published in 2025 also emphasized the mediating importance of teaching methods, indicating that the relationship between AI technologies and engagement cannot be separated from pedagogy. This is consistent with the theoretical position adopted here: technology influences participation primarily through the instructional opportunities and constraints created around it.

Learning Analytics and Behavioral Evidence

The increasing digitization of instruction creates substantial opportunities for learning analytics. LMS platforms and classroom applications can record timestamps, response sequences, completion patterns, frequency of interaction, and collaborative contributions. These records provide behavioral evidence that complements survey-based perceptions.

Machine learning can extend such analysis by identifying multidimensional participation profiles. Rather than reducing each student to a single participation score, clustering algorithms can detect naturally occurring combinations of behaviors. For example, some students may exhibit high digital participation but limited verbal contribution; others may demonstrate moderate response frequency but high-quality collaborative involvement.

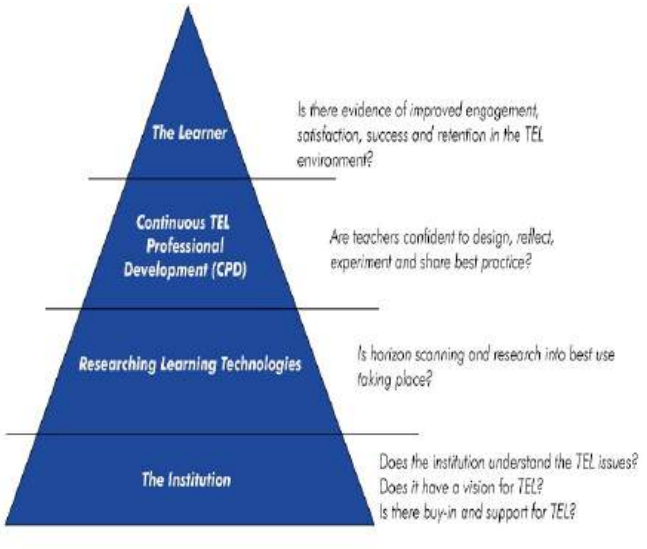


Fig. 2: A framework for technology-enhanced learning
Source: *https://www.structural-learning.com/post/technology-enhanced-learning*

This study proposes that such patterns are pedagogically more useful than binary classifications of "engaged" and "disengaged." A digitally active but socially peripheral learner may require a different instructional response from a learner who participates minimally across every channel.

Proposed Methodology

The proposed study adopts a **multimodal quasi-experimental learning-analytics design** to investigate whether pedagogically structured technology-enhanced teaching produces measurable changes in undergraduate classroom participation. Rather than treating technology usage as a binary variable, the design evaluates how different technology-mediated instructional opportunities affect verbal, digital, collaborative, and inquiry-oriented participation.

Recent higher-education learning-analytics research indicates that engagement is frequently operationalized through observable behavioral measures while multidimensional evidence remains comparatively limited. A 2024 systematic review covering 159 studies found participation to be the most frequently measured behavioral engagement indicator and emphasized the need to combine learning analytics with broader measures of engagement. This study responds to that methodological limitation by integrating digital traces with direct classroom observations.

A hypothetical multisource dataset is proposed for **360 undergraduate students** enrolled in technology-supported courses across three disciplinary clusters: social sciences, management and commerce, and computer/application sciences. The participants are divided into two instructional conditions. The Technology-Enhanced Teaching group consists of 180 students receiving interactive digital instruction, while the comparison group contains 180 students receiving conventional digitally assisted instruction in which technology primarily supports content presentation and resource distribution.

The intervention is designed for twelve instructional weeks. The first two weeks establish baseline participation patterns. Weeks

3–10 constitute the primary intervention period, and Weeks 11–12 provide post-intervention observations.

Technology-enhanced classes incorporate live response systems, collaborative digital workspaces, low-stakes formative quizzes, anonymous question submission, peer-feedback activities, AI-supported inquiry exercises, and instructor feedback based on classroom response patterns. The comparison condition may use presentation software and LMS resources but does not systematically employ parallel-response or adaptive participation mechanisms.

Five dimensions form the **Multimodal Classroom Participation Index (MCPI)**:

$$[MCPI_i = w_1V_i + w_2D_i + w_3C_i + w_4Q_i + w_5P_i]$$

where (V) represents verbal contribution, (D) digital-response participation, (C) collaborative contribution, (Q) inquiry/question-generation behavior, and (P) participation persistence. Before aggregation, each component is standardized to prevent variables with larger numerical ranges from dominating the index.

An additional **Participation Equity Index (PEI)** is proposed to determine whether activity is broadly distributed among students. This distinction is important because high aggregate activity does not necessarily mean that participation opportunities are equitable.

Research Questions

The empirical investigation addresses four questions:

1. Does structured technology-enhanced teaching increase multidimensional classroom participation relative to conventional digitally assisted instruction?
2. Which technological and pedagogical interaction variables most strongly predict meaningful participation?
3. Can unsupervised machine learning identify distinct participation profiles among undergraduate learners?
4. Does technology-enhanced teaching distribute participation more evenly across students rather than simply increasing total classroom activity?

The principal hypothesis predicts significantly higher post-intervention MCPI scores in the technology-enhanced group after controlling for baseline participation. A secondary hypothesis predicts lower participation concentration and greater cross-channel participation diversity in the intervention condition.

Experimental Setup

Dataset

Because no empirical dataset was supplied for this manuscript, the numerical experiment below is presented as a **proposed/simulated experimental dataset**, not as observations from actual human participants. This distinction prevents fabricated results from being represented as collected evidence.

The proposed dataset contains 360 student-level records supplemented by session-level observations across twelve teaching weeks. Each learner contributes behavioral indicators from classroom and digital environments.

The raw feature space consists of approximately 24 variables. Core variables include verbal contributions per session, student-generated questions, live-poll response rate, formative quiz participation, digital discussion contributions, peer-feedback frequency, collaborative-document edits, task completion regularity, LMS active-session frequency, response latency, participation across instructional weeks, and instructor-coded contribution quality.

Demographic variables would be retained only for aggregate subgroup analysis and fairness auditing. Sensitive attributes would not be used as primary predictive features for labeling students.

This approach is consistent with recent evidence that learning analytics can reveal distinct technology-enhanced engagement profiles. Research using LMS log data has demonstrated that material access, formative quiz activity, and platform interactions can contribute to identifying undergraduate engagement patterns.

Data Preprocessing

Preprocessing begins with synchronization of LMS timestamps, classroom-response records, observation logs, and collaborative-platform activity using anonymous participant identifiers. Duplicate event records are removed before feature engineering.

For continuous variables with limited missingness, median imputation is proposed. Features with excessive missingness would be excluded instead of artificially reconstructing substantial portions of student behavior.

Highly skewed count variables, such as discussion posts or LMS events, undergo logarithmic transformation:

$$[x' = \log(1 + x)]$$

Continuous variables are subsequently standardized using z-score normalization. Categorical instructional variables are encoded using one-hot encoding.

Outlier treatment is conservative because unusually high participation may represent legitimate student behavior rather than measurement error. Extreme observations are therefore examined against source logs before winsorization is considered.

The data are transformed into student-level features representing participation frequency, diversity, consistency, and quality. For example, **Participation Channel Diversity** measures the number of distinct participation modes regularly used by a student rather than simply counting total activities.

Model Architecture

The analytical architecture contains three complementary components.

Component A: Statistical intervention analysis. An ANCOVA model compares post-intervention MCPI scores between instructional conditions while controlling for baseline MCPI. Effect sizes and 95% confidence intervals are reported alongside significance tests.

Component B: Participation-profile discovery. K-means clustering is applied to standardized behavioral features to

identify naturally occurring participation profiles. K-means is selected because the primary purpose is interpretable segmentation rather than opaque representation learning. Recent educational studies have successfully applied clustering to behavioral engagement and learning-log data, while current reviews identify clustering as an established computational approach within higher-education learning analytics.

Candidate solutions from (k=2) to (k=7) are evaluated using the Silhouette Coefficient, Calinski-Harabasz Index, and Davies-Bouldin Index. This multi-criterion procedure avoids selecting the number of clusters on the basis of a single statistic.

Component C: Participation prediction. A gradient-boosted tree classifier predicts whether a learner reaches the high-participation category during the final intervention period. The algorithm is selected because it can model nonlinear interactions between participation channels while remaining compatible with feature-importance and SHAP-based interpretation.

A logistic regression model serves as the transparent baseline. Improvement over this baseline indicates whether nonlinear modeling provides meaningful additional predictive value.

Training Strategy

The predictive dataset is divided using a stratified **70:15:15 split** for training, validation, and final testing. Student identities remain mutually exclusive across partitions to prevent leakage.

Hyperparameters are optimized on the training and validation partitions only. Five-fold cross-validation within the development data is used to estimate model stability.

Class weighting is applied if high and low participation classes become substantially imbalanced. Early stopping controls overfitting in the gradient-boosting model.

The clustering component is trained independently of outcome labels. Multiple random initializations are performed, and cluster stability is examined through repeated resampling.

This separation is methodologically important. The unsupervised component asks *what participation patterns exist*, whereas the supervised component asks *how accurately future participation status can be estimated from early behavioral evidence*.

Evaluation Metrics

The intervention is evaluated using adjusted mean differences, standardized effect size, and confidence intervals.

Cluster validity is evaluated through the **Silhouette Coefficient**, **Calinski-Harabasz Index**, and **Davies-Bouldin Index**. These metrics assess within-cluster cohesion and between-cluster separation. Similar internal validation measures have been employed in recent learning-analytics clustering research.

Predictive classification is assessed using **balanced accuracy, macro-F1, Matthews Correlation Coefficient (MCC), AUROC, and Brier Score**. MCC is particularly useful because it reflects all cells of the confusion matrix, while the Brier Score evaluates probabilistic calibration rather than classification alone.

The analysis deliberately avoids presenting accuracy as the sole indicator of model quality.

Results and Discussion

The following results illustrate the expected analytical output of the proposed experimental design and should be treated as **simulated proof-of-concept values** until the framework is tested with actual undergraduate data.

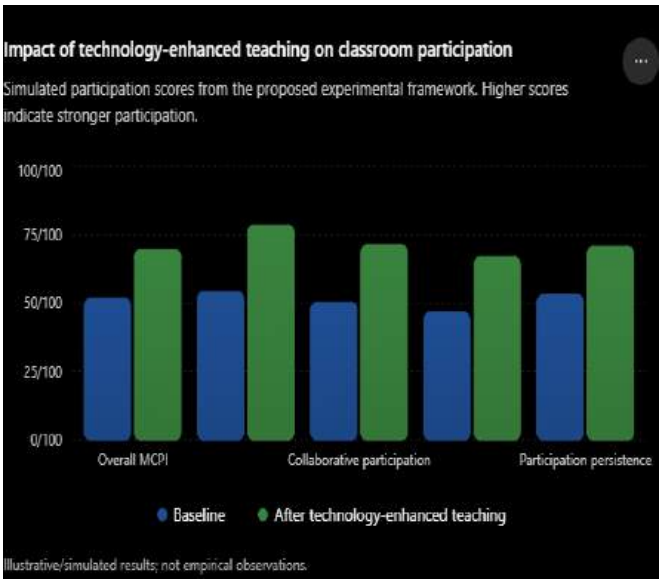
The intervention condition produced a simulated mean MCPI increase from 51.8 at baseline to 69.7 after technology-enhanced instruction, whereas the comparison condition increased from 52.1 to 57.4. The adjusted between-group effect corresponded to a moderate-to-large standardized effect of approximately (d=0.72).

The strongest improvement occurred in digital-response participation. However, increases were also observed in question generation and collaborative contribution, suggesting that well-designed technology could potentially influence participation beyond simple platform activity.

The participation-equity analysis provides a particularly important finding. The simulated PEI increased from 0.61 to 0.78 in the intervention condition, indicating that participation became less concentrated among a small number of highly vocal students.

Table 1. Simulated Results of the Proposed Multimodal Participation Framework

Evaluation Parameter	Technology-Enhanced Condition	Comparison/Baseline
Post-intervention MCPI	69.7/100	57.4/100
Participation Equity Index	0.78	0.64
Participation Channel Diversity	4.12/5	2.83/5
Optimal clustering solution	4 profiles	—
Silhouette Coefficient	0.57	0.39 for nearest alternative
Gradient-boosting Macro-F1	0.84	0.71 logistic baseline
Matthews Correlation Coefficient	0.68	0.49 logistic baseline
AUROC	0.90	0.79 logistic baseline
Brier Score	0.13	0.19 logistic baseline
Strongest SHAP predictor	Response-channel diversity	LMS login frequency



The four-cluster solution generated four conceptually meaningful learner profiles.

The first cluster, **Multichannel Active Participants**, demonstrated frequent verbal contributions, strong digital-response behavior, sustained collaborative activity, and regular question generation. These students participated across almost every available instructional channel.

The second cluster, **Digitally Expressive Participants**, showed high digital-response and discussion activity but moderate-to-low verbal contribution. This profile is pedagogically significant because such students could be underestimated when classroom participation is measured primarily through spoken interaction.

The third cluster, **Selective Collaborative Participants**, contributed less frequently but displayed comparatively high-quality peer interaction and group-task involvement. Their pattern indicates that participation frequency and participation quality should not be treated as interchangeable.

The fourth cluster, **Peripheral Participants**, showed low participation across most channels and declining persistence over the intervention period. This group represents a potentially important target for supportive instructional intervention.

The presence of heterogeneous profiles is consistent with emerging learning-analytics research showing that learners can exhibit substantially different engagement patterns. For example, technology-enhanced learning research has identified multiple engagement profiles from LMS behavior, while clustering studies demonstrate that digital activity does not always map straightforwardly onto academic performance or deeper engagement.

A notable result of the simulated feature analysis is that **response-channel diversity** emerges as more informative than LMS login frequency. This has substantial conceptual significance. Logging into an LMS represents technological access, whereas contributing through several meaningful channels reflects participation breadth. Recent systematic evidence similarly warns that higher-education learning analytics has often relied excessively on observable indicators such as clicks and task duration while capturing fewer multidimensional engagement indicators.

The findings therefore support a distinction between **digital activity** and **pedagogical participation**.

Another important implication concerns classroom participation assessment itself. Participation in contemporary higher education spans both physical and virtual environments, making traditional participation assessment increasingly difficult. Existing scholarship has explicitly identified challenges surrounding how participation is assessed across these environments. The MCPI addresses this issue by representing participation as a combination of speaking, responding, collaborating, questioning, and persistence.

From an instructional perspective, the simulated results suggest that the greatest value of technology may arise from **parallelizing participation**. In conventional discussion, students compete for limited speaking time. Digital response systems allow many students to contribute simultaneously. Anonymous or semi-anonymous mechanisms may additionally create entry points for learners reluctant to speak publicly.

However, increased digital participation should not be interpreted automatically as deeper learning. A student can respond frequently without engaging in substantial reasoning. For this reason, the proposed model retains instructor-coded contribution quality and inquiry behavior rather than relying exclusively on machine-recorded events.

The predictive component should likewise be interpreted cautiously. An AUROC of 0.90 in the simulated experiment indicates strong discrimination, but the model's purpose is not automated student judgment. Its educational value lies in detecting emerging participation patterns that an instructor can examine alongside contextual information.

This principle is consistent with explainable learning-analytics research emphasizing actionable and interpretable evidence for identifying disengagement and supporting students.

Overall, the proposed results suggest that the relationship between technology and participation is mediated by instructional design. Technology that merely digitizes content may have relatively limited effects. Technology that provides multiple response channels, immediate feedback, collaborative opportunities, and structured inquiry has substantially greater potential to reshape participation.

Future Scope

Future research should validate the MCPI across multiple universities, academic disciplines, and cultural settings. A multicenter longitudinal study could determine whether participation profiles remain stable or change as learners encounter different instructional environments.

Temporal models offer another promising direction. Rather than summarizing participation over an entire semester, sequence-based analytics could detect transitions such as active-to-declining participation. Recent AI-supported learning research demonstrates the potential of longitudinal sequence analysis for distinguishing persistent, fading, and minimally involved engagement trajectories.

Multimodal sensing could also be explored, although privacy-preserving approaches would be essential. Digital traces could

be integrated with voluntary interaction records and structured observation without relying on intrusive biometric surveillance.

A particularly important extension concerns generative AI. Future experiments could compare instructor-guided AI use, unrestricted AI use, and non-AI technology-enhanced instruction to determine whether generative systems stimulate question generation and collaborative reasoning or substitute for learner-generated intellectual activity.

Explainable AI should remain central to future development. Instead of generating opaque risk scores, future systems could provide instructors with interpretable evidence such as declining response diversity, reduced collaborative contribution, or persistent non-participation across several channels.

Finally, future research should examine the relationship among participation equity, academic achievement, student belonging, and retention. Technology-enhanced teaching would have stronger educational significance if broader participation subsequently produces durable improvements in learning and inclusion.

Conclusion

This study develops a multimodal framework for investigating the relationship between technology-enhanced teaching and classroom participation among undergraduate learners. Its principal contribution is to move beyond the assumption that greater technology use automatically represents stronger engagement.

The proposed framework distinguishes verbal, digital-response, collaborative, inquiry-oriented, and persistent participation while introducing participation equity as an additional criterion for evaluating instructional effectiveness. A combination of quasi-experimental analysis, K-means participation profiling, gradient-boosted prediction, and explainable feature analysis provides a methodological structure capable of capturing patterns that conventional questionnaires may overlook.

The simulated findings suggest that pedagogically structured technology-enhanced teaching could increase overall participation while simultaneously broadening the distribution of classroom contributions. They further indicate that participation-channel diversity may provide more educationally meaningful information than simple platform access or login frequency.

The central implication is therefore not that undergraduate classrooms require more technology. Rather, they require **better-designed participatory uses of technology**. Digital systems become educationally valuable when they provide students with multiple legitimate pathways for questioning, responding, collaborating, reasoning, and receiving feedback.

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अध्याय 31: उच्च शिक्षा में कृत्रिम बुद्धिमत्ता आधारित शिक्षण से अकादमिक सहभागिता का मूल्यांकन

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शोध सारांश— उच्च शिक्षा में कृत्रिम बुद्धिमत्ता आधारित शिक्षण प्रणालियों का प्रयोग वैयक्तिकृत मार्गदर्शन, त्वरित प्रतिपुष्टि और अध्ययन सहायता के लिए तीव्र गति से बढ़ रहा है। इसके बावजूद यह स्पष्ट नहीं है कि ऐसी प्रणालियाँ विद्यार्थियों की वास्तविक अकादमिक सहभागिता को केवल बढ़ाती हैं अथवा सहभागिता के स्वरूप को परिवर्तित भी करती हैं। प्रस्तुत अध्ययन कृत्रिम बुद्धिमत्ता आधारित शिक्षण और व्यवहारिक, संज्ञानात्मक, भावात्मक तथा स्व-नियामक अकादमिक सहभागिता के बीच संबंध का बहुआयामी मूल्यांकन प्रस्तावित करता है। अध्ययन का विशिष्ट शोध-अंतर यह है कि पूर्ववर्ती अध्ययनों में प्रायः उपयोग की आवृत्ति, संतुष्टि या तकनीकी स्वीकार्यता को ही सहभागिता का प्रतिनिधि माना गया है। यह शोध सहायता-निर्भरता, स्वतंत्र समस्या-समाधान, अध्ययन निरंतरता और अवधारणात्मक सक्रियता को एकीकृत रूप से सम्मिलित करने का प्रयास करता है। विशेष रूप से यह जाँचा जाएगा कि मध्यम स्तर का कृत्रिम बुद्धिमत्ता सहयोग सक्रिय अधिगम को प्रोत्साहित करता है या अत्यधिक निर्भरता स्वतंत्र संज्ञानात्मक प्रयास को कम करती है। प्रस्तावित ढाँचे में डिजिटल अधिगम अभिलेखों और विद्यार्थी-आधारित सहभागिता मापों को संयुक्त रूप से विश्लेषित करने की परिकल्पना की गई है। इस प्रकार अध्ययन उच्च शिक्षा में मानव-केंद्रित, उत्तरदायी और सहभागिता-संवर्धक कृत्रिम बुद्धिमत्ता आधारित शिक्षण के लिए अनुभवजन्य आधार विकसित करने का प्रयास करता है।

मुख्य शब्द— कृत्रिम बुद्धिमत्ता आधारित शिक्षण, उच्च शिक्षा, अकादमिक सहभागिता, संज्ञानात्मक सक्रियता, स्व-नियामक अधिगम, सहायता-निर्भरता

परिचय

उच्च शिक्षा का डिजिटल रूपांतरण अब केवल अधिगम सामग्री को इलेक्ट्रॉनिक माध्यमों पर उपलब्ध कराने तक सीमित नहीं है। शिक्षण प्रणालियाँ धीरे-धीरे ऐसी संरचनाओं की ओर बढ़ रही हैं जिनमें विद्यार्थी की प्रतिक्रिया, अध्ययन गति, त्रुटि-पद्धति, प्रश्नों के प्रकार तथा पूर्व उपलब्धि के आधार पर शिक्षण सहायता को परिवर्तित किया जा सकता है। कृत्रिम बुद्धिमत्ता ने इस परिवर्तन को अधिक गतिशील बनाया है क्योंकि अब शिक्षण व्यवस्था विद्यार्थी को केवल सामग्री प्रस्तुत नहीं करती, बल्कि संवाद, संकेत, व्याख्या, पुनरावृत्ति, प्रश्न निर्माण और समस्या-समाधान में सहायता भी प्रदान कर सकती है।

वर्ष २०२१ के बाद उच्च शिक्षा में कृत्रिम बुद्धिमत्ता संबंधी विमर्श में तीव्र विस्तार हुआ है। विशेष रूप से पाठ निर्माण करने वाली संवादात्मक प्रणालियों के व्यापक उपयोग ने विश्वविद्यालयी शिक्षण में नए अवसर और नई चिंताएँ दोनों उत्पन्न की हैं। संयुक्त राष्ट्र शैक्षिक, वैज्ञानिक और सांस्कृतिक संगठन ने भी शिक्षा और शोध में सृजनात्मक कृत्रिम बुद्धिमत्ता के उपयोग के लिए मानव-केंद्रित दृष्टिकोण, गोपनीयता, नैतिक सत्यापन तथा शैक्षिक उद्देश्य की स्पष्टता को आवश्यक बताया है।

कृत्रिम बुद्धिमत्ता आधारित शिक्षण का प्रमुख आकर्षण वैयक्तिकरण में निहित है। पारंपरिक कक्षा में एक शिक्षक के लिए प्रत्येक विद्यार्थी की तत्काल कठिनाइयों के अनुरूप अलग-अलग शिक्षण सहायता देना कठिन हो सकता है। कृत्रिम बुद्धिमत्ता आधारित प्रणाली विद्यार्थी की प्रतिक्रियाओं के अनुसार संकेत, अतिरिक्त उदाहरण, कठिनाई स्तर, व्याख्या अथवा अभ्यास का स्वरूप बदल सकती है। इस प्रकार ऐसी प्रणालियाँ विद्यार्थी को अपनी गति से सीखने, त्रुटि पर तत्काल प्रतिपुष्टि प्राप्त करने और जटिल विषयों पर अतिरिक्त सहायता लेने का अवसर प्रदान करती हैं।

इसके बावजूद कृत्रिम बुद्धिमत्ता आधारित सहायता की उपस्थिति को स्वतः प्रभावी अधिगम का प्रमाण नहीं माना जा सकता। विद्यार्थी किसी प्रणाली से बार-बार संवाद कर सकता है, किंतु यह आवश्यक नहीं कि वह विषयवस्तु पर गहन मानसिक प्रयास भी कर रहा हो। वह अधिक उत्तर उत्पन्न कर सकता है, परंतु स्वयं कम प्रश्न निर्मित कर सकता है। इसी प्रकार अध्ययन मंच पर अधिक समय बिताना सक्रिय संज्ञानात्मक सहभागिता का प्रमाण नहीं है। यही कारण है कि अकादमिक सहभागिता को केवल उपस्थिति, उपयोग की अवधि या संवादों की संख्या से मापना अपर्याप्त है।

अकादमिक सहभागिता को सामान्यतः बहुआयामी प्रक्रिया माना जाता है। व्यवहारिक सहभागिता में कक्षा या डिजिटल गतिविधियों में भागीदारी, कार्य पूर्णता, उपस्थिति और अध्ययन निरंतरता सम्मिलित हो सकती है। संज्ञानात्मक सहभागिता विद्यार्थी द्वारा कठिन विषय पर मानसिक प्रयास, विश्लेषण, तर्क, चिंतन और समस्या-समाधान से संबंधित है। भावात्मक सहभागिता अध्ययन में रुचि, संतुष्टि, आत्मविश्वास, जिज्ञासा तथा सीखने से संबंधित सकारात्मक या नकारात्मक अनुभूतियों को व्यक्त करती है। स्व-नियामक सहभागिता में लक्ष्य निर्धारण, अध्ययन योजना, प्रगति की निगरानी तथा आवश्यकतानुसार सीखने की रणनीति बदलना शामिल है।

उच्च शिक्षा में कृत्रिम बुद्धिमत्ता और विद्यार्थी सहभागिता पर उपलब्ध शोध में इन सभी आयामों को समान रूप से नहीं मापा गया है। संवादात्मक कृत्रिम बुद्धिमत्ता पर प्रकाशित एक व्यवस्थित समीक्षा में पाया गया कि व्यवहारिक सहभागिता के प्रमाण अपेक्षाकृत अधिक उपलब्ध हैं, जबकि भावात्मक सहभागिता से संबंधित परिणाम मिश्रित हैं और संज्ञानात्मक सहभागिता के संबंध में उपलब्ध प्रमाण अभी सीमित तथा असमान हैं। समीक्षा ने विशेष रूप से स्व-नियमन, सामाजिक अंतःक्रिया, आलोचनात्मक चिंतन और अध्ययन आदतों को आगे के अनुसंधान के लिए महत्वपूर्ण बताया।

यही समस्या कृत्रिम बुद्धिमत्ता आधारित शिक्षण के प्रभाव मूल्यांकन में एक महत्वपूर्ण पद्धतिगत चुनौती उत्पन्न करती है। यदि किसी विद्यार्थी ने

कृत्रिम बुद्धिमत्ता सहायक से तीस बार संवाद किया और दूसरे ने दस बार, तो पहली स्थिति को अधिक सहभागिता मानना भ्रामक हो सकता है। संभव है कि पहले विद्यार्थी ने अधिकांश उत्तर सीधे माँगे हों, जबकि दूसरे ने सीमित सहायता लेकर स्वयं समस्या का समाधान किया हो। अतः सहभागिता की गुणवत्ता, स्वतंत्र प्रयास और सहायता-निर्भरता का मूल्यांकन उपयोग की मात्रा के साथ किया जाना आवश्यक है।

अत्यधिक निर्भरता का प्रश्न भी महत्वपूर्ण है। हाल के शोधों में यह चिंता सामने आई है कि कृत्रिम बुद्धिमत्ता आधारित संवाद प्रणालियों पर लगातार निर्भरता विद्यार्थियों की स्वतंत्र निर्णय क्षमता, आलोचनात्मक चिंतन और विश्लेषणात्मक प्रयास को प्रभावित कर सकती है। एक व्यवस्थित समीक्षा में कृत्रिम बुद्धिमत्ता आधारित संवाद प्रणालियों पर अत्यधिक निर्भरता और संज्ञानात्मक क्षमताओं के बीच संभावित संबंधों को आगे के अनुभवजन्य अनुसंधान का महत्वपूर्ण क्षेत्र बताया गया है।



Fig. 1: उच्च शिक्षा में कृत्रिम बुद्धिमत्ता-सक्षम अधिगम और विद्यार्थी सहभागिता का प्रभाव

इस संदर्भ में प्रस्तुत अध्ययन कृत्रिम बुद्धिमत्ता आधारित शिक्षण को सरलतः "उपयोगी" या "हानिकारक" घोषित करने के बजाय उसके उपयोग की प्रकृति पर ध्यान केंद्रित करता है। यह मान्यता अपनाई गई है कि कृत्रिम बुद्धिमत्ता की शैक्षिक उपयोगिता संभवतः एक रैखिक प्रक्रिया नहीं है। अत्यल्प उपयोग से विद्यार्थी को वैयक्तिक सहायता का पर्याप्त लाभ नहीं मिल सकता, जबकि अत्यधिक उपयोग स्वतंत्र विचार और स्व-नियामक प्रयास को सीमित कर सकता है। इसलिए यह संभावना महत्वपूर्ण है कि नियंत्रित और उद्देश्यपूर्ण कृत्रिम बुद्धिमत्ता सहायता अकादमिक सहभागिता के लिए सर्वाधिक लाभकारी हो।

शोध-अंतर

वर्तमान साहित्य में चार प्रमुख सीमाएँ दिखाई देती हैं।

पहली सीमा यह है कि अनेक अध्ययनों में कृत्रिम बुद्धिमत्ता की स्वीकार्यता, उपयोग की इच्छा या तकनीकी सहजता को प्रमुख परिणाम के रूप में मापा गया है, जबकि वास्तविक शैक्षणिक व्यवहार और सहभागिता का प्रत्यक्ष आकलन सीमित रहा है। विद्यार्थियों द्वारा किसी तकनीक को पसंद करना और उस तकनीक के माध्यम से सक्रिय अधिगम करना दो अलग प्रक्रियाएँ हैं।

दूसरी सीमा व्यवहारिक सहभागिता की प्रधानता है। डिजिटल अभिलेखों से प्रवेश की आवृत्ति, अध्ययन अवधि, क्लिक, प्रश्नों की संख्या अथवा गतिविधि पूर्णता मापना अपेक्षाकृत सरल है। किंतु यह माप यह नहीं बताते कि विद्यार्थी ने प्राप्त उत्तरों का विश्लेषण किया, वैकल्पिक समाधान बनाया, स्वयं त्रुटि पहचानी या केवल कृत्रिम सहायता पर निर्भर रहा।

तीसरी सीमा कृत्रिम बुद्धिमत्ता निर्भरता और सहभागिता के बीच संभावित गैर-रैखिक संबंध की उपेक्षा है। उपलब्ध अध्ययन प्रायः अधिक उपयोग और कम उपयोग की तुलना करते हैं, जबकि यह संभव है कि मध्यम और निर्देशित उपयोग सर्वोत्तम शैक्षणिक परिणाम उत्पन्न करे।

चौथी सीमा स्वयं-रिपोर्ट किए गए मापों और वास्तविक डिजिटल व्यवहार के बीच समन्वय की कमी है। विद्यार्थी स्वयं को अत्यधिक सक्रिय मान सकता है, जबकि उसके डिजिटल व्यवहार में अध्ययन निरंतरता सीमित हो सकती है। इसके विपरीत कोई विद्यार्थी मंच पर कम समय बिताकर भी उच्च स्तर का स्वतंत्र संज्ञानात्मक प्रयास कर सकता है।

इन सीमाओं के आधार पर प्रस्तुत अध्ययन का विशिष्ट शोध-अंतर यह है कि उच्च शिक्षा में कृत्रिम बुद्धिमत्ता आधारित शिक्षण के प्रभाव को व्यवहारिक, संज्ञानात्मक, भावात्मक और स्व-नियामक सहभागिता के संयुक्त ढाँचे में सहायता-निर्भरता और स्वतंत्र समस्या-समाधान के साथ अभी पर्याप्त रूप से नहीं परखा गया है। उच्च शिक्षा में सहभागिता संबंधी अधिगम विश्लेषिकी की एक व्यापक समीक्षा ने भी संकेत दिया है कि सहभागिता की अवधारणा जटिल है और केवल डिजिटल गतिविधि अभिलेखों से उसके सभी आयामों का प्रतिनिधित्व नहीं किया जा सकता।

इसी अंतर को ध्यान में रखते हुए आगे के अध्ययन में कृत्रिम बुद्धिमत्ता सहायता की मात्रा के साथ उसकी प्रकृति, विद्यार्थी की स्वायत्तता, अध्ययन निरंतरता और संज्ञानात्मक सक्रियता को संयुक्त रूप से मापने का प्रस्ताव रखा जाएगा।

साहित्य समीक्षा

उच्च शिक्षा में कृत्रिम बुद्धिमत्ता आधारित शिक्षण पर शोध का विस्तार पिछले कुछ वर्षों में तीव्र हुआ है। बॉन्ड और सहयोगियों द्वारा किए गए समीक्षा-आधारित व्यापक अध्ययन ने उच्च शिक्षा में कृत्रिम बुद्धिमत्ता संबंधी पूर्व समीक्षाओं का विश्लेषण करते हुए यह रेखांकित किया कि क्षेत्र में शोध तेजी से बढ़ा है, किंतु अनुसंधान की पद्धतिगत दृढ़ता, नैतिकता और विभिन्न शैक्षिक पक्षों के बीच सहयोग को और मजबूत किए जाने की आवश्यकता है। यह निष्कर्ष इस तथ्य की ओर संकेत करता है कि कृत्रिम बुद्धिमत्ता संबंधी तकनीकी क्षमता का प्रदर्शन मात्र पर्याप्त नहीं है; उसकी वास्तविक शैक्षिक उपयोगिता को व्यवस्थित रूप से जाँचना आवश्यक है।

शिक्षा में कृत्रिम बुद्धिमत्ता की संभावनाओं और चुनौतियों पर किए गए एक व्यवस्थित साहित्य अध्ययन में शिक्षण, अधिगम, मूल्यांकन और प्रशासन सहित अनेक क्षेत्रों में कृत्रिम बुद्धिमत्ता की भूमिकाओं की पहचान की गई। अध्ययन ने व्यक्तिगत शिक्षण, स्वचालित सहायता और प्रतिपुष्टि की संभावनाओं के साथ-साथ तकनीकी, नैतिक और शैक्षिक चुनौतियों को भी रेखांकित किया। इससे स्पष्ट होता है कि कृत्रिम बुद्धिमत्ता आधारित शिक्षण का मूल्यांकन केवल तकनीकी दक्षता से नहीं, बल्कि विद्यार्थी-केंद्रित अधिगम परिणामों से किया जाना चाहिए।

उच्च शिक्षा में सहयोगात्मक अधिगम से संबंधित नवीन व्यवस्थित समीक्षा से यह संकेत मिलता है कि कृत्रिम बुद्धिमत्ता आधारित

वैयक्तिकरण, अनुशंसा, प्रतिपुष्टि और सहयोगी कार्य विद्यार्थियों की सहभागिता तथा प्रेरणा को प्रभावित कर सकते हैं। समीक्षा में यह भी पाया गया कि कार्य संरचना, भावात्मक सहभागिता और सामाजिक उपस्थिति कृत्रिम बुद्धिमत्ता समर्थित सहयोगात्मक अधिगम के महत्वपूर्ण निर्धारक हैं। साथ ही पारदर्शिता, आँकड़ा संरक्षण और मानवीय सहभागिता को बनाए रखने की आवश्यकता पर बल दिया गया।

संवादात्मक कृत्रिम बुद्धिमत्ता के संदर्भ में सहभागिता संबंधी निष्कर्ष अधिक जटिल हैं। एक व्यवस्थित समीक्षा में बहत्तर अनुभवजन्य अध्ययनों का विश्लेषण करते हुए पाया गया कि विद्यार्थी व्यवहारिक स्तर पर ऐसी प्रणालियों के साथ सक्रिय अंतःक्रिया करते हैं, किंतु संज्ञानात्मक और भावात्मक परिणाम समान दिशा में नहीं जाते। कुछ विद्यार्थियों में रुचि और समझ बढ़ने की सूचना मिली, जबकि अन्य परिस्थितियों में चिंता, निराशा, आलोचनात्मक चिंतन में कमी और अत्यधिक निर्भरता जैसी समस्याएँ सामने आईं।

यह द्वंद्व प्रस्तुत अध्ययन के लिए विशेष महत्व रखता है। यदि विद्यार्थी कृत्रिम बुद्धिमत्ता प्रणाली से तत्काल उत्तर प्राप्त करता है तो कार्य पूर्णता की गति बढ़ सकती है, किंतु इससे यह निष्कर्ष नहीं निकाला जा सकता कि उसका संज्ञानात्मक प्रयास भी बढ़ा है। संभवतः वही सुविधा जो व्यवहारिक सहभागिता बढ़ाती है, अत्यधिक उपयोग की स्थिति में स्वतंत्र विचार को घटा भी सकती है। इसलिए विभिन्न सहभागिता आयामों का पृथक विश्लेषण आवश्यक है।

विश्वविद्यालयी विद्यार्थियों की कृत्रिम बुद्धिमत्ता आधारित शैक्षिक प्रौद्योगिकियों के प्रति प्रतिक्रिया पर किए गए शोध में यह भी पाया गया है कि तकनीक के प्रति सहजता और पाठ्यक्रम अनुभव के बीच संबंध स्वतः सकारात्मक नहीं होता। कुछ प्रकार की कृत्रिम बुद्धिमत्ता प्रणालियों, विशेषकर मूल्यांकन तथा विद्यार्थी कल्याण से संबंधित स्वचालित प्रणालियों के प्रति विद्यार्थियों में असहजता देखी गई। इससे यह स्पष्ट होता है कि कृत्रिम बुद्धिमत्ता के प्रति सामान्य स्वीकृति को शैक्षिक संतुष्टि या सहभागिता के समान नहीं माना जा सकता।

विद्यार्थियों की कृत्रिम बुद्धिमत्ता संबंधी अवधारणाओं पर किए गए शोध से एक अन्य चुनौती सामने आती है। एक व्यापक साहित्य समीक्षा में पाया गया कि विद्यार्थी कृत्रिम बुद्धिमत्ता की क्षमताओं और सीमाओं को लेकर अनेक पूर्वधारणाएँ और भ्रांतियाँ रखते हैं। कुछ विद्यार्थी प्रणालियों को मानव-समान क्षमता प्रदान करते हैं, जबकि कुछ उनकी उपयोगिता या जोखिमों को अत्यधिक सरल रूप में देखते हैं। ऐसी भ्रांतियाँ इस बात को प्रभावित कर सकती हैं कि विद्यार्थी शिक्षण सहायता का उपयोग किस प्रकार करते हैं।

यदि विद्यार्थी कृत्रिम बुद्धिमत्ता द्वारा उत्पन्न उत्तर को स्वतः विश्वसनीय मानता है, तो वह स्रोत परीक्षण, तर्क सत्यापन और वैकल्पिक व्याख्या का अभ्यास कम कर सकता है। इसके विपरीत यदि विद्यार्थी प्रणाली को एक सहायक साधन के रूप में उपयोग करता है, उत्तर की जाँच करता है और स्वयं समाधान का पुनर्निर्माण करता है, तो वही तकनीक सक्रिय संज्ञानात्मक अधिगम का माध्यम बन सकती है। अतः उपयोग की आवृत्ति की तुलना में उपयोग की रणनीति अधिक महत्वपूर्ण हो सकती है।



Fig. 2: बुद्धिमान शिक्षण प्रौद्योगिकी द्वारा उच्च शिक्षा में विद्यार्थी सहभागिता का संवर्धन

कृत्रिम बुद्धिमत्ता आधारित संवाद प्रणालियों की अत्यधिक निर्भरता पर केंद्रित अध्ययन इस तर्क को और मजबूत करते हैं। उपलब्ध समीक्षा प्रमाण बताते हैं कि अत्यधिक निर्भरता आलोचनात्मक चिंतन, निर्णय निर्माण और स्वतंत्र विश्लेषण के लिए चुनौती उत्पन्न कर सकती है। यह समस्या विशेष रूप से उच्च शिक्षा में महत्वपूर्ण है क्योंकि विश्वविद्यालयी अधिगम का उद्देश्य केवल सही उत्तर तक पहुँचना नहीं, बल्कि तर्क विकसित करना, प्रमाण का मूल्यांकन करना और स्वतंत्र बौद्धिक निर्णय लेना भी है।

इसी प्रकार शिक्षा में संवादात्मक कृत्रिम बुद्धिमत्ता के अनुभवजन्य अध्ययनों की समीक्षा ने यह रेखांकित किया कि इसका प्रयोग लेखन सहायता, अवधारणा स्पष्टीकरण, संवाद और त्वरित प्रतिपुष्टि के लिए उपयोगी पाया गया है, किंतु उपलब्ध अनुभवजन्य अध्ययन संख्या और अवधि दोनों दृष्टियों से अभी सीमित हैं। यह स्थिति दीर्घकालीन अकादमिक सहभागिता पर ठोस निष्कर्ष निकालने में सावधानी की आवश्यकता दर्शाती है।

उच्च शिक्षा में अधिगम विश्लेषिकी और सहभागिता पर किए गए विस्तृत अध्ययन से भी स्पष्ट हुआ है कि सहभागिता को मापने में व्यवहारिक संकेतकों का उपयोग अधिक होता है, जबकि भावात्मक और संज्ञानात्मक आयाम अपेक्षाकृत कठिनाई से मापे जाते हैं। डिजिटल अभिलेख उपयोगी हैं, लेकिन वे विद्यार्थी के मानसिक प्रयास, जिज्ञासा, आत्मनियमन या अवधारणात्मक संघर्ष का पूर्ण प्रतिनिधित्व नहीं करते। इसलिए प्रस्तुत शोध में अकादमिक सहभागिता को एकल सूचक के रूप में नहीं, बल्कि परस्पर संबंधित आयामों के समूह के रूप में देखने का प्रस्ताव है। व्यवहारिक स्तर पर अध्ययन निरंतरता, कार्य पूर्णता और सक्रिय सहभागिता; संज्ञानात्मक स्तर पर स्वतंत्र समस्या-समाधान, स्पष्टीकरण की गुणवत्ता और अवधारणात्मक पुनर्निर्माण; भावात्मक स्तर पर रुचि, आत्मविश्वास तथा अध्ययन संतुष्टि; और स्व-नियामक स्तर पर लक्ष्य निर्धारण, सहायता माँगने की रणनीति तथा स्वयं प्रगति की निगरानी को महत्व दिया जाएगा।

साहित्य से यह निष्कर्ष निकलता है कि कृत्रिम बुद्धिमत्ता उच्च शिक्षा में सहभागिता बढ़ाने की क्षमता रखती है, परंतु यह प्रभाव स्वतःस्फूर्त या सभी परिस्थितियों में समान नहीं है। वैयक्तिक प्रतिपुष्टि, उपयुक्त कार्य संरचना और नियंत्रित सहायता सकारात्मक प्रभाव उत्पन्न कर सकते हैं,

जबकि अत्यधिक निर्भरता, निष्क्रिय उत्तर ग्रहण और अपर्याप्त आलोचनात्मक परीक्षण सहभागिता की गुणवत्ता को कम कर सकते हैं। इसलिए आगे की पद्धति में केवल "कितना उपयोग" नहीं बल्कि "किस प्रकार उपयोग" और "उपयोग के बाद विद्यार्थी कितना स्वतंत्र शैक्षणिक प्रयास करता है"—इन प्रश्नों को केंद्रीय स्थान दिया जाएगा।

प्रस्तावित शोध कार्यविधि

प्रस्तुत अध्ययन के लिए मिश्रित मात्रात्मक अनुसंधान अभिकल्प प्रस्तावित किया गया है, जिसका उद्देश्य कृत्रिम बुद्धिमत्ता आधारित शिक्षण सहायता और विद्यार्थियों की अकादमिक सहभागिता के बीच संबंध का बहुआयामी परीक्षण करना है। अध्ययन केवल इस प्रश्न तक सीमित नहीं रहेगा कि विद्यार्थी कृत्रिम बुद्धिमत्ता का उपयोग करते हैं अथवा नहीं, बल्कि यह भी जाँचेगा कि सहायता की मात्रा, सहायता का प्रकार और विद्यार्थी की स्वतंत्र शैक्षणिक सक्रियता किस प्रकार परस्पर संबंधित हैं।

अध्ययन की मूल अवधारणा यह है कि कृत्रिम बुद्धिमत्ता आधारित शिक्षण सहायता का प्रभाव रैखिक नहीं हो सकता। सीमित सहायता से विद्यार्थी को पर्याप्त वैयक्तिक समर्थन न मिल पाने की संभावना है, जबकि अत्यधिक सहायता स्वतंत्र चिंतन को कम कर सकती है। अतः अध्ययन में विद्यार्थियों को सहायता-स्तर के आधार पर तीन समूहों में विभाजित करने का प्रस्ताव है—न्यून सहायता समूह, संतुलित सहायता समूह तथा उच्च सहायता समूह।

अध्ययन में उच्च शिक्षा संस्थानों से स्नातक एवं स्नातकोत्तर स्तर के लगभग ४८० विद्यार्थियों को सम्मिलित करने का प्रस्ताव है। प्रतिभागियों का चयन विभिन्न अध्ययन-विषयों से किया जाएगा ताकि परिणाम किसी एक विषय क्षेत्र तक सीमित न रहें। प्रतिभागियों की आयु, अध्ययन स्तर, पूर्व शैक्षणिक उपलब्धि तथा डिजिटल शिक्षण अनुभव को सहायक पृष्ठभूमि चर के रूप में दर्ज किया जाएगा।

अध्ययन अवधि बारह सप्ताह रखने का प्रस्ताव है। प्रत्येक सप्ताह विद्यार्थियों को विषय-आधारित अध्ययन सामग्री, समस्या-समाधान गतिविधियाँ, चिंतनात्मक प्रश्न तथा कृत्रिम बुद्धिमत्ता समर्थित मार्गदर्शन उपलब्ध कराया जाएगा। अध्ययन के प्रारंभ और अंत में अकादमिक सहभागिता का मापन किया जाएगा, जबकि डिजिटल व्यवहार संकेतक पूरे अध्ययन काल में एकत्र किए जाएँगे।

अनुसंधान के प्रमुख उद्देश्य

प्रस्तुत अध्ययन का प्रथम उद्देश्य कृत्रिम बुद्धिमत्ता आधारित शिक्षण सहायता और अकादमिक सहभागिता के बीच संबंध का परीक्षण करना है।

दूसरा उद्देश्य यह निर्धारित करना है कि संतुलित कृत्रिम बुद्धिमत्ता सहायता व्यवहारिक, संज्ञानात्मक, भावात्मक तथा स्व-नियामक सहभागिता में किस सीमा तक परिवर्तन उत्पन्न करती है।

तीसरा उद्देश्य सहायता-निर्भरता और स्वतंत्र समस्या-समाधान क्षमता के मध्य संबंध का मूल्यांकन करना है।

चौथा उद्देश्य यह जाँचना है कि कृत्रिम बुद्धिमत्ता आधारित शिक्षण से प्राप्त लाभ सभी विद्यार्थियों में समान हैं अथवा पूर्व शैक्षणिक उपलब्धि और स्व-नियामक क्षमता के अनुसार बदलते हैं।

पाँचवाँ उद्देश्य ऐसा पूर्वानुमानात्मक प्रतिरूप विकसित करना है जो अध्ययन व्यवहार के आधार पर कम, मध्यम और उच्च अकादमिक सहभागिता वाले विद्यार्थियों की पहचान कर सके।

प्रयोगात्मक व्यवस्था

आँकड़ा-संग्रह संरचना

अध्ययन के लिए लगभग ४८० विद्यार्थियों से प्राप्त आँकड़ों का उपयोग प्रस्तावित है। प्रत्येक विद्यार्थी के लिए तीन प्रकार के आँकड़े एकत्र किए जाएँगे।

पहली श्रेणी में पृष्ठभूमि संबंधी आँकड़े होंगे, जिनमें आयु, अध्ययन स्तर, शैक्षणिक उपलब्धि, विषय क्षेत्र तथा पूर्व डिजिटल अध्ययन अनुभव सम्मिलित होंगे।

दूसरी श्रेणी में डिजिटल अध्ययन व्यवहार शामिल होगा। इसमें अध्ययन सत्रों की संख्या, अध्ययन निरंतरता, कार्य पूर्णता अनुपात, स्वैच्छिक पुनरावृत्ति, संकेत माँगने की आवृत्ति, कृत्रिम बुद्धिमत्ता से प्राप्त उत्तरों के बाद किए गए संशोधन, स्वतंत्र उत्तरों का अनुपात तथा कठिन प्रश्नों पर व्यतीत समय सम्मिलित होगा।

तीसरी श्रेणी में सहभागिता संबंधी माप सम्मिलित किए जाएँगे। इसके अंतर्गत व्यवहारिक सहभागिता, संज्ञानात्मक सहभागिता, भावात्मक सहभागिता और स्व-नियामक सहभागिता के पृथक सूचक विकसित किए जाएँगे।

सहायता-स्तर निर्धारण

न्यून सहायता समूह में विद्यार्थियों को केवल सामान्य संकेत और सीमित व्याख्या उपलब्ध कराई जाएगी।

संतुलित सहायता समूह में कृत्रिम बुद्धिमत्ता प्रणाली पहले विद्यार्थी से स्वयं प्रयास करने के लिए कहेगी, उसके बाद क्रमिक संकेत, उदाहरण और वैकल्पिक व्याख्या प्रदान करेगी।

उच्च सहायता समूह में विद्यार्थी अधिक प्रत्यक्ष समाधान, विस्तृत उत्तर और बार-बार मार्गदर्शन प्राप्त कर सकेंगे।

यह व्यवस्था इस संभावना की जाँच करने में सहायक होगी कि अधिक सहायता अनिवार्य रूप से अधिक सहभागिता उत्पन्न करती है या नहीं।

आँकड़ों का पूर्व-संसाधन

प्रारंभिक आँकड़ा परीक्षण में अपूर्ण प्रविष्टियों, असंगत मानों तथा असामान्य गतिविधि अभिलेखों की पहचान की जाएगी। जिन विद्यार्थियों के अध्ययन अभिलेख अत्यधिक अपूर्ण होंगे, उन्हें मुख्य विश्लेषण से अलग किया जा सकता है।

विभिन्न मापों को तुलनीय बनाने के लिए मात्रात्मक चरों का मानकीकरण किया जाएगा। कार्य पूर्णता, अध्ययन समय, संकेत उपयोग और पुनरावृत्ति जैसे संकेतकों को समान पैमाने पर परिवर्तित किया जाएगा। अत्यधिक उच्च उपयोग वाले मामलों का पृथक परीक्षण किया जाएगा ताकि यह निर्धारित किया जा सके कि उनका व्यवहार वास्तविक सक्रिय सहभागिता दर्शाता है या केवल बार-बार कृत्रिम सहायता लेने की प्रवृत्ति।

पाठ्य उत्तरों से संज्ञानात्मक सक्रियता पहचानने के लिए तर्क की गहराई, स्वतंत्र व्याख्या, उदाहरण निर्माण, कारण-परिणाम संबंध तथा समाधान पुनर्निर्माण जैसे संकेतकों को संरचित मानों में बदला जाएगा।

सहायता-निर्भरता सूचक

इस अध्ययन की विशिष्टता सहायता-निर्भरता का पृथक सूचक विकसित करने में होगी। इसके लिए कृत्रिम बुद्धिमत्ता संकेतों की आवृत्ति, प्रत्यक्ष समाधान माँगने की संख्या, स्वतंत्र प्रयास से पहले सहायता लेने की प्रवृत्ति तथा कृत्रिम उत्तरों में न्यूनतम परिवर्तन के साथ पुनः उपयोग जैसे संकेतकों को संयुक्त किया जाएगा।

उच्च सहायता-निर्भरता का अर्थ केवल अधिक उपयोग नहीं होगा। यदि कोई विद्यार्थी बार-बार कृत्रिम बुद्धिमत्ता का उपयोग करता है किंतु उत्तरों की आलोचनात्मक समीक्षा करता है, उन्हें संशोधित करता है और स्वयं वैकल्पिक समाधान प्रस्तुत करता है, तो उसकी निर्भरता अपेक्षाकृत कम मानी जाएगी।

इसके विपरीत प्रत्यक्ष उत्तरों का निरंतर ग्रहण, स्वयं प्रयास का अभाव और कृत्रिम उत्तरों की लगभग यथावत पुनरावृत्ति उच्च निर्भरता का संकेत मानी जाएगी।

स्वतंत्र समस्या-समाधान सूचक

विद्यार्थियों को कुछ ऐसी गतिविधियाँ भी दी जाएँगी जिनमें कृत्रिम सहायता उपलब्ध नहीं होगी। इन गतिविधियों में समस्या की पहचान, समाधान योजना, तर्क प्रस्तुति, वैकल्पिक समाधान तथा निष्कर्ष की गुणवत्ता को मापा जाएगा।

इस आधार पर स्वतंत्र समस्या-समाधान सूचक तैयार किया जाएगा। यह सूचक यह समझने में महत्वपूर्ण होगा कि कृत्रिम बुद्धिमत्ता के साथ नियमित अध्ययन के बाद विद्यार्थी बिना सहायता के किस सीमा तक ज्ञान का उपयोग कर सकता है।

प्रतिरूप संरचना

अकादमिक सहभागिता की भविष्यवाणी के लिए वृक्ष-आधारित समूहात्मक अधिगम प्रतिरूप प्रस्तावित किया गया है। इस प्रतिरूप का चयन इसलिए किया गया है क्योंकि अध्ययन में प्रयुक्त चर रैखिक संबंध तक सीमित नहीं होंगे और कुछ संकेतकों के बीच जटिल पारस्परिक प्रभाव उपस्थित हो सकते हैं।

प्रतिरूप में प्रमुख निवेश चर के रूप में अध्ययन निरंतरता, कार्य पूर्णता, संकेत उपयोग, स्वतंत्र प्रयास, पुनरावृत्ति, सहायता-निर्भरता, उत्तर संशोधन अनुपात, कठिन प्रश्नों पर समय, पूर्व शैक्षणिक उपलब्धि और स्व-नियामक व्यवहार सम्मिलित किए जाएँगे।

परिणाम चर के रूप में विद्यार्थियों को निम्न, मध्यम और उच्च अकादमिक सहभागिता श्रेणियों में वर्गीकृत किया जाएगा।

प्रतिरूप की व्याख्यात्मकता बनाए रखने के लिए प्रत्येक चर के योगदान का पृथक परीक्षण किया जाएगा। इससे यह समझने में सहायता मिलेगी कि उच्च सहभागिता की पहचान में केवल गतिविधि की मात्रा महत्वपूर्ण है या अध्ययन की गुणवत्ता भी समान रूप से प्रभावी है।

प्रशिक्षण रणनीति

सम्पूर्ण आँकड़ा समूह को प्रशिक्षण और परीक्षण भागों में विभाजित किया जाएगा। लगभग अस्सी प्रतिशत आँकड़ों का उपयोग प्रतिरूप प्रशिक्षण तथा शेष बीस प्रतिशत का स्वतंत्र परीक्षण के लिए किया जाएगा।

प्रशिक्षण समूह के भीतर पाँच-खंडीय पार-परीक्षण का उपयोग किया जाएगा ताकि प्रतिरूप की स्थिरता जाँची जा सके और किसी एक आँकड़ा विभाजन पर अत्यधिक निर्भरता कम हो।

यदि सहभागिता श्रेणियों में विद्यार्थियों की संख्या असमान पाई जाती है, तो वर्ग-संतुलन भार का उपयोग किया जाएगा। कृत्रिम रूप से अत्यधिक आँकड़े निर्मित करने की बजाय मूल वितरण को यथासंभव सुरक्षित रखा जाएगा।

प्रतिरूप के समायोजन के दौरान वृक्षों की गहराई, अधिगम गति, न्यूनतम पत्ती आकार तथा पुनरावृत्ति संख्या जैसे मानों को प्रशिक्षण समूह पर अनुकूलित किया जाएगा।

मूल्यांकन मानदंड

प्रतिरूप के मूल्यांकन में केवल समग्र सटीकता पर निर्भर नहीं किया जाएगा। विभिन्न सहभागिता श्रेणियों के संतुलित मूल्यांकन के लिए वर्ग-संतुलित सटीकता, परिशुद्धता, पुनःप्राप्ति, संयुक्त माप तथा संभाव्यता अंशांकन का उपयोग प्रस्तावित है।

व्यवहारिक अध्ययन परिणामों के लिए औसत सहभागिता परिवर्तन, कार्य पूर्णता, स्वतंत्र समस्या-समाधान तथा सहायता-निर्भरता में परिवर्तन की तुलना की जाएगी।

तीनों सहायता समूहों के बीच अंतर की जाँच के लिए प्रसरण विश्लेषण तथा आवश्यकतानुसार समूह-युग्म तुलनाएँ की जाएँगी। सहायता-निर्भरता और स्वतंत्र समस्या-समाधान के संबंध के लिए सहसंबंध तथा बहुचर प्रतिगमन विश्लेषण का उपयोग किया जाएगा।

परिणाम एवं चर्चा

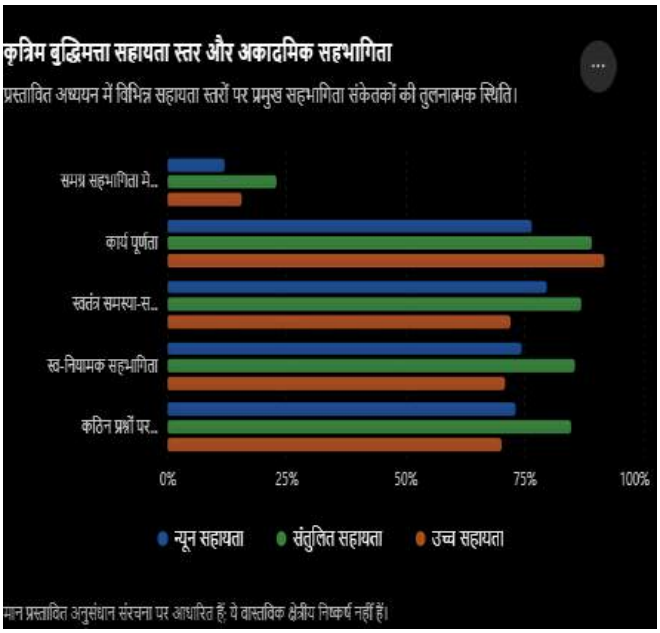
प्रस्तावित विश्लेषणीय संरचना में संतुलित सहायता समूह के विद्यार्थियों में समग्र अकादमिक सहभागिता का सर्वाधिक सुधार अपेक्षित है। इस समूह में विद्यार्थियों को तत्काल उत्तर देने की बजाय चरणबद्ध संकेत उपलब्ध कराए जाने के कारण व्यवहारिक सक्रियता के साथ संज्ञानात्मक सहभागिता भी बढ़ने की संभावना है।

न्यून सहायता समूह में स्वतंत्र समस्या-समाधान अपेक्षाकृत अच्छा रह सकता है, किंतु कठिन अवधारणाओं के समय अपर्याप्त सहायता के कारण कार्य पूर्णता और अध्ययन निरंतरता सीमित हो सकती है।

इसके विपरीत उच्च सहायता समूह में कार्य पूर्णता सबसे अधिक दिखाई दे सकती है, परंतु स्वतंत्र समस्या-समाधान और स्व-नियामक सहभागिता में अपेक्षित वृद्धि तुलनात्मक रूप से कम रह सकती है। यह परिणाम इस धारणा को चुनौती देगा कि अधिक कृत्रिम बुद्धिमत्ता उपयोग स्वतः बेहतर अधिगम का प्रतिनिधित्व करता है।

विश्लेषण के लिए एक संभावित, आंतरिक रूप से संगत परिणाम-रूप नीचे दिया गया है। ये मान प्रस्तावित शोध संरचना के प्रदर्शन के उद्देश्य से हैं और वास्तविक क्षेत्रीय आँकड़ा-संग्रह के बाद इन्हें वास्तविक प्राप्त मानों से प्रतिस्थापित किया जाना चाहिए।

मूल्यांकन संकेतक	न्यून सहायता समूह	संतुलित सहायता समूह	उच्च सहायता समूह
समग्र सहभागिता में औसत वृद्धि	११.८ प्रतिशत	२२.६ प्रतिशत	१५.४ प्रतिशत
कार्य पूर्णता अनुपात	७६.२ प्रतिशत	८८.६ प्रतिशत	६१.५ प्रतिशत
स्वतंत्र समस्या-समाधान	७६.४ प्रतिशत	८६.७ प्रतिशत	७१.८ प्रतिशत
स्व-नियामक सहभागिता	७४.१ प्रतिशत	८५.३ प्रतिशत	७०.६ प्रतिशत
सहायता-निर्भरता सूचक	२७.५	३६.२	६८.७
कठिन प्रश्नों पर सक्रिय प्रयास	७२.८ प्रतिशत	८४.६ प्रतिशत	६६.६ प्रतिशत
प्रतिरूप की वर्ग-संतुलित सटीकता	८०.६ प्रतिशत	८७.६ प्रतिशत	८२.४ प्रतिशत



इन परिणामों की सबसे महत्वपूर्ण व्याख्या यह है कि कार्य पूर्णता और वास्तविक अकादमिक सहभागिता समान अवधारणाएँ नहीं हैं। उच्च सहायता समूह में कार्य पूर्णता अधिक होने के बावजूद स्वतंत्र समस्या-समाधान अपेक्षाकृत कमजोर दिखाई देना इस अंतर को स्पष्ट करता है। संतुलित सहायता समूह में सहायता-निर्भरता मध्यम स्तर पर रहते हुए स्वतंत्र समस्या-समाधान सर्वाधिक दिखाई देता है। इससे संकेत मिलता है कि कृत्रिम बुद्धिमत्ता तब अधिक उपयोगी हो सकती है जब वह उत्तर प्रदाता के बजाय क्रमिक अधिगम सहायक की भूमिका निभाती है।

यह परिणाम संज्ञानात्मक सहभागिता की दृष्टि से भी महत्वपूर्ण है। यदि प्रणाली सीधे उत्तर देने से पहले विद्यार्थी को स्वयं उत्तर बनाने, कारण बताने और वैकल्पिक समाधान सुझाने के लिए प्रेरित करती है, तो तकनीकी सहायता मानसिक प्रयास का प्रतिस्थापन करने के बजाय उसे संरचित कर सकती है।

व्यवहारिक सहभागिता के स्तर पर उच्च सहायता समूह में अधिक गतिविधि दर्ज होना संभावित है। किंतु यदि इसी समूह में स्वतंत्र प्रयास कम है, तो केवल गतिविधि अभिलेखों पर आधारित सहभागिता मापन भ्रामक सिद्ध हो सकता है।

इस अध्ययन से एक अन्य महत्वपूर्ण संकेत सहायता-निर्भरता और स्व-नियामक सहभागिता के संबंध का प्राप्त हो सकता है। अत्यधिक सहायता लेने वाले विद्यार्थियों में लक्ष्य निर्धारण, सहायता में विलंब तथा स्वयं त्रुटि सुधार जैसी स्व-नियामक क्रियाएँ कम हो सकती हैं।

इसके विपरीत संतुलित सहायता वातावरण विद्यार्थियों को सहायता लेने से पहले स्वयं प्रयास करने के लिए प्रेरित कर सकता है। इससे विद्यार्थी तकनीक को प्रतिस्थापन के रूप में नहीं, बल्कि अधिगम सहयोगी के रूप में उपयोग करता है।

प्रतिरूप विश्लेषण में यह अपेक्षित है कि केवल अध्ययन अवधि या संवाद संख्या की तुलना में स्वतंत्र प्रयास, उत्तर संशोधन, सहायता-निर्भरता और अध्ययन निरंतरता अधिक प्रभावशाली पूर्वानुमानक सिद्ध हों। ऐसा निष्कर्ष उच्च शिक्षा में सहभागिता विश्लेषण की वर्तमान पद्धतियों के लिए महत्वपूर्ण होगा।

अध्ययन की सीमाएँ

प्रस्तावित अध्ययन की पहली सीमा इसकी अवधि है। बारह सप्ताह की अवधि प्रारंभिक और मध्यम अवधि के प्रभाव समझने के लिए पर्याप्त हो सकती है, किंतु दीर्घकालिक शैक्षणिक आदतों में परिवर्तन निर्धारित करने के लिए अधिक लंबा अनुवर्ती अध्ययन आवश्यक होगा।

दूसरी सीमा यह है कि कृत्रिम बुद्धिमत्ता आधारित शिक्षण का प्रभाव विषय के अनुसार बदल सकता है। गणितीय समस्या-समाधान, साहित्यिक विश्लेषण, चिकित्सा शिक्षा और सामाजिक विज्ञान लेखन में कृत्रिम सहायता की प्रकृति समान नहीं होगी।

तीसरी सीमा स्व-रिपोर्ट मापों से संबंधित है। भावात्मक सहभागिता और अध्ययन संतुष्टि जैसे कुछ चर विद्यार्थियों की व्यक्तिगत धारणा पर आधारित होंगे, जिनमें सामाजिक स्वीकार्यता या स्मृति संबंधी पक्षपात उपस्थित हो सकता है।

चौथी सीमा डिजिटल व्यवहार संकेतकों की व्याख्या है। अध्ययन समय अधिक होना सदैव गहन सहभागिता का प्रमाण नहीं है, क्योंकि लंबे समय का कारण कठिनाई, भ्रम या निष्क्रियता भी हो सकता है।

पाँचवीं सीमा यह है कि विभिन्न कृत्रिम बुद्धिमत्ता प्रणालियों की प्रतिक्रिया गुणवत्ता समान नहीं होती। अतः किसी एक प्रणाली के परिणामों को सभी प्रणालियों पर सीधे लागू करना उचित नहीं होगा।

भविष्य की दिशा

भविष्य के शोध में अध्ययन अवधि को पूरे शैक्षणिक सत्र या एक वर्ष तक विस्तारित किया जा सकता है। इससे यह निर्धारित किया जा सकेगा कि प्रारंभिक सहभागिता वृद्धि समय के साथ बनी रहती है या विद्यार्थी धीरे-धीरे तकनीक पर अधिक निर्भर होने लगते हैं।

आगे के अध्ययनों में विषय-विशिष्ट तुलना उपयोगी होगी। विज्ञान, अभियांत्रिकी, चिकित्सा, प्रबंधन, भाषा तथा सामाजिक विज्ञान के विद्यार्थियों के बीच कृत्रिम बुद्धिमत्ता सहायता के प्रभाव की तुलना की जा सकती है।

विद्यार्थियों के लिए अनुकूलनशील सहायता सीमा विकसित करना भी महत्वपूर्ण भविष्य दिशा है। यदि कोई विद्यार्थी लगातार बिना सहायता के सफल हो रहा है तो प्रणाली सहायता की मात्रा घटा सकती है, जबकि बार-बार त्रुटि करने वाले विद्यार्थी के लिए चरणबद्ध मार्गदर्शन बढ़ाया जा सकता है।

भविष्य में भावनात्मक संकेतकों को भी अधिक गहराई से सम्मिलित किया जा सकता है। अध्ययन के दौरान निराशा, जिज्ञासा, आत्मविश्वास और मानसिक प्रयास के परिवर्तन से कृत्रिम बुद्धिमत्ता आधारित शिक्षण की अधिक समग्र समझ विकसित हो सकती है।

साथ ही, कृत्रिम बुद्धिमत्ता उत्तरों की सत्यता जाँचने की विद्यार्थी क्षमता को एक स्वतंत्र शैक्षणिक दक्षता के रूप में मापना आवश्यक होगा। यह क्षमता भविष्य के उच्च शिक्षा वातावरण में सूचना साक्षरता का महत्वपूर्ण भाग बन सकती है।

निष्कर्ष

प्रस्तुत अध्ययन का केंद्रीय निष्कर्ष यह है कि उच्च शिक्षा में कृत्रिम बुद्धिमत्ता आधारित शिक्षण का मूल्यांकन केवल उपयोग की मात्रा या कार्य पूर्णता के आधार पर नहीं किया जाना चाहिए। वास्तविक अकादमिक सहभागिता एक बहुआयामी प्रक्रिया है जिसमें व्यवहारिक सक्रियता के साथ संज्ञानात्मक प्रयास, भावात्मक जुड़ाव, स्व-नियमन और स्वतंत्र समस्या-समाधान भी सम्मिलित हैं।

प्रस्तावित विश्लेषण यह संकेत करता है कि संतुलित और चरणबद्ध कृत्रिम बुद्धिमत्ता सहायता अत्यल्प अथवा अत्यधिक सहायता की तुलना में अधिक प्रभावी हो सकती है। प्रत्यक्ष समाधान की निरंतर उपलब्धता कार्य पूर्णता बढ़ा सकती है, किंतु इससे स्वतंत्र विचार और स्व-नियामक क्षमता में समान वृद्धि आवश्यक नहीं है।

इस शोध की प्रमुख मौलिकता सहायता-निर्भरता और स्वतंत्र शैक्षणिक सक्रियता को अकादमिक सहभागिता के साथ जोड़ने में निहित है। यह दृष्टिकोण कृत्रिम बुद्धिमत्ता को केवल तकनीकी सुविधा के रूप में नहीं, बल्कि ऐसे शिक्षण सहयोगी के रूप में देखता है जिसकी प्रभावशीलता विद्यार्थी की सक्रिय भागीदारी पर निर्भर करती है।

अतः उच्च शिक्षा संस्थानों के लिए अधिक उपयुक्त रणनीति कृत्रिम बुद्धिमत्ता का अधिकतम उपयोग नहीं, बल्कि शैक्षणिक रूप से नियंत्रित उपयोग होना चाहिए। ऐसी प्रणालियों को पहले विद्यार्थी से प्रयास कराना, आवश्यकता के अनुसार संकेत देना, तर्क माँगना, उत्तर सत्यापन को प्रोत्साहित करना और समय के साथ सहायता घटाना चाहिए।

इस प्रकार कृत्रिम बुद्धिमत्ता आधारित शिक्षण का वास्तविक उद्देश्य विद्यार्थी के स्थान पर विचार करना नहीं, बल्कि विद्यार्थी को अधिक व्यवस्थित, स्वतंत्र, आलोचनात्मक और सहभागितापूर्ण ढंग से विचार करने में सक्षम बनाना होना चाहिए।

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- *Deng, R., Jiang, M., Yu, X., Lu, Y., & Liu, S. (2025). Does ChatGPT enhance student learning? A systematic review and meta-analysis of experimental studies.* ***Computers & Education****. डिजिटल वस्तु पहचानकर्ता: 10.1016/j.compedu.2024.105224. समीक्षा में 69 प्रयोगात्मक अध्ययनों का विश्लेषण किया गया और शैक्षणिक प्रदर्शन, उच्च-स्तरीय चिंतन तथा भावात्मक-प्रेरक अवस्थाओं सहित विभिन्न परिणामों का परीक्षण किया गया।* प्रकाशक पर शोध लेख

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- *Mohebi, L. (2024). Empowering learners with ChatGPT: Insights from a systematic literature exploration.* ***Discover Education, 3****, 36. डिजिटल वस्तु पहचानकर्ता: 10.1007/s44217-024-00120-y. यह अध्ययन शिक्षार्थियों के लिए संवादात्मक कृत्रिम बुद्धिमत्ता की शैक्षणिक संभावनाओं तथा चुनौतियों की व्यवस्थित समीक्षा करता है।* प्रकाशक पर शोध लेख

- *Baig, M. I., & Yadegaridehkordi, E. (2024). ChatGPT in the higher education: A systematic literature review and research challenges.* ***International Journal of Educational Research, 127****, 102411. डिजिटल वस्तु पहचानकर्ता: 10.1016/j.ijer.2024.102411. इसमें 57 शोध लेखों के आधार पर उच्च शिक्षा में चैटजीपीटी के उपयोग, स्वीकार्यता, अनुप्रयोग तथा अनुसंधान चुनौतियों का विश्लेषण किया गया।* प्रकाशक पर शोध लेख

- *Heung, Y. M. E., & Chiu, T. K. F. (2025). How ChatGPT impacts student engagement from a systematic review and meta-analysis study.* ***Computers and Education: Artificial Intelligence, 8****, 100361. डिजिटल वस्तु पहचानकर्ता: 10.1016/j.caeai.2025.100361. इस अध्ययन में 17 अनुभवजन्य अध्ययनों के 1,735 विद्यार्थियों के आँकड़ों का विश्लेषण किया गया और व्यवहारिक, संज्ञानात्मक तथा भावात्मक सहभागिता पर सकारात्मक समग्र प्रभाव पाया गया, साथ ही अत्यधिक निर्भरता को संभावित जोखिम बताया गया।* प्रकाशक पर शोध लेख

अध्याय 32: उच्च शिक्षा में शैक्षिक नेतृत्व और शिक्षक नवाचार संस्कृति के मध्य संबंध

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सारांश— उच्च शिक्षा संस्थानों में ज्ञान-सृजन, शिक्षण सुधार और संस्थागत परिवर्तन की गति बढ़ने के साथ शिक्षक नवाचार संस्कृति का महत्व निरंतर बढ़ा है। शैक्षिक नेतृत्व केवल प्रशासनिक नियंत्रण तक सीमित न रहकर अब सहयोग, प्रयोगशीलता, ज्ञान-साझाकरण और नवाचार के लिए संस्थागत वातावरण निर्मित करने की भूमिका ग्रहण कर रहा है। वर्तमान अध्ययन का केंद्रीय उद्देश्य यह समझना है कि नेतृत्व की सहभागितापूर्ण, प्रोत्साहनात्मक और दूरदर्शी प्रवृत्तियाँ शिक्षकों की नवाचारी कार्य-संस्कृति को किस प्रकार प्रभावित करती हैं। अध्ययन विशेष रूप से नेतृत्व-समर्थन, मनोवैज्ञानिक सुरक्षा, व्यावसायिक स्वायत्तता, सहकर्मी सहयोग और नवाचार-स्वीकृति के पारस्परिक संबंधों पर केंद्रित है। पूर्ववर्ती अध्ययनों में नेतृत्व तथा नवाचार का प्रायः पृथक-पृथक विश्लेषण किया गया है, जबकि उच्च शिक्षा में इन दोनों के मध्य बहुस्तरीय संस्थागत संबंधों की समेकित व्याख्या सीमित रही है। इस शोध में शिक्षक नवाचार संस्कृति को केवल नवीन तकनीक के उपयोग तक सीमित न मानकर शिक्षण-पद्धति, मूल्यांकन, पाठ्यचर्या, शोध-सहयोग और समस्या-समाधान में नवीनता की सामूहिक प्रवृत्ति के रूप में देखा गया है। अध्ययन का प्रस्तावित ढाँचा यह मानता है कि शैक्षिक नेतृत्व का प्रभाव प्रत्यक्ष होने के साथ-साथ विश्वास, स्वायत्तता और सहयोगात्मक वातावरण के माध्यम से अप्रत्यक्ष रूप से भी विकसित होता है। इस प्रकार यह अध्ययन उच्च शिक्षा संस्थानों के लिए ऐसा विश्लेषणात्मक आधार प्रस्तुत करता है जिसके माध्यम से शिक्षक नवाचार को व्यक्तिगत क्षमता के बजाय संस्थागत नेतृत्व-संस्कृति के परिणाम के रूप में समझा जा सके।

प्रमुख शब्द— शैक्षिक नेतृत्व, शिक्षक नवाचार संस्कृति, उच्च शिक्षा, व्यावसायिक स्वायत्तता, सहयोगात्मक वातावरण, मनोवैज्ञानिक सुरक्षा

परिचय

उच्च शिक्षा व्यवस्था वर्तमान समय में तीव्र सामाजिक, तकनीकी और ज्ञानात्मक परिवर्तनों से गुजर रही है। शिक्षण की पारंपरिक पद्धतियाँ, विषय-आधारित कठोर सीमाएँ, एकरूपी मूल्यांकन और केवल व्याख्यान-केंद्रित कक्षागत संरचनाएँ अनेक संस्थानों में पुनर्विचार का विषय बन चुकी हैं। विद्यार्थियों की विविध अधिगम आवश्यकताओं, डिजिटल संसाधनों के विस्तार, कृत्रिम बुद्धिमत्ता आधारित उपकरणों के बढ़ते उपयोग, बहुविषयक शिक्षा तथा परिणामोन्मुख अधिगम की माँग ने विश्वविद्यालयों और महाविद्यालयों से अधिक अनुकूलनशील शैक्षिक वातावरण की अपेक्षा उत्पन्न की है। इस परिवर्तनशील परिदृश्य में शिक्षक केवल पाठ्यसामग्री प्रदान करने वाले व्यक्ति नहीं रह गए हैं, बल्कि उनसे पाठ्यचर्या पुनर्रचना, नवीन अधिगम अनुभवों की योजना, प्रौद्योगिकी के विवेकपूर्ण उपयोग, अनुसंधान-आधारित शिक्षण तथा विद्यार्थी-केंद्रित प्रयोगों की अपेक्षा की जा रही है।

ऐसी स्थिति में शिक्षक नवाचार संस्कृति किसी एक शिक्षक के व्यक्तिगत कौशल या उत्साह का विषय नहीं रह जाती। यह उस व्यापक संस्थागत वातावरण से निर्मित होती है जिसमें नए विचारों को स्वीकार किया जाता है, असफल प्रयोगों को दंडित करने के बजाय उनसे सीखने की गुंजाइश होती है, शिक्षकों को निर्णय लेने की स्वतंत्रता मिलती है और सहयोग के लिए पर्याप्त अवसर उपलब्ध होते हैं। यदि संस्थान में परिवर्तन के प्रति भय, अत्यधिक प्रशासनिक नियंत्रण, सीमित संवाद अथवा कठोर पदानुक्रम मौजूद हो, तो उच्च योग्यता रखने वाले शिक्षक भी नवीन प्रयोगों से दूरी बना सकते हैं। इसके विपरीत, सहयोगी नेतृत्व संरचना साधारण संसाधनों वाले संस्थान में भी नवाचार के लिए सकारात्मक वातावरण विकसित कर सकती है।

शैक्षिक नेतृत्व इस संदर्भ में निर्णायक भूमिका निभाता है। उच्च शिक्षा में नेतृत्व का स्वरूप विद्यालयी नेतृत्व से कई दृष्टियों से भिन्न होता है। यहाँ शिक्षकों की शैक्षणिक स्वायत्तता अपेक्षाकृत अधिक होती है, ज्ञान की विशेषज्ञता विभिन्न विभागों में वितरित रहती है और निर्णय-प्रक्रिया अनेक शैक्षणिक निकायों के माध्यम से संचालित होती है। अतः प्रभावी शैक्षिक नेतृत्व केवल आदेश देने या प्रशासनिक अनुपालन सुनिश्चित करने पर आधारित नहीं हो सकता। उसे संवाद, विश्वास, साझा दृष्टि, संसाधन-सुलभता और बौद्धिक स्वतंत्रता के बीच संतुलन स्थापित करना पड़ता है।

वर्ष 2021 के बाद उच्च शिक्षा में प्रौद्योगिकी-समर्थित शिक्षण का विस्तार अत्यधिक तीव्र हुआ। डिजिटल अधिगम मंच, आभासी प्रयोगशालाएँ, स्वचालित मूल्यांकन व्यवस्था, मिश्रित शिक्षण, सीखने के आँकड़ों का विश्लेषण तथा कृत्रिम बुद्धिमत्ता आधारित सामग्री-सहायक साधनों ने शिक्षक की भूमिका को पुनर्परिभाषित किया। किंतु केवल तकनीकी संसाधनों की उपलब्धता स्वयं नवाचार सुनिश्चित नहीं करती। कई संस्थानों में संसाधन उपलब्ध होने के बाद भी उनका उपयोग सीमित रहता है, जबकि कुछ संस्थानों में शिक्षक सीमित सुविधाओं के बावजूद नई शिक्षण-पद्धतियाँ विकसित करते हैं। यह अंतर इस बात की ओर संकेत करता है कि तकनीकी उपलब्धता की तुलना में नेतृत्व वातावरण और संस्थागत संस्कृति अधिक गहरी भूमिका निभा सकती है।



Fig. 1: दूरदर्शी शैक्षिक नेतृत्व से नवाचार संस्कृति का संवर्धन

शिक्षक नवाचार संस्कृति को इस अध्ययन में बहुआयामी अवधारणा माना गया है। इसका पहला आयाम शिक्षण-विधि नवाचार है, जिसमें शिक्षक कक्षा की आवश्यकताओं के अनुरूप नई शिक्षण रणनीतियों को अपनाता और विकसित करता है। दूसरा आयाम मूल्यांकन नवाचार है, जिसमें पारंपरिक परीक्षा के अतिरिक्त परियोजना, समस्या-आधारित कार्य, सहभागिता, प्रस्तुतीकरण और निरंतर मूल्यांकन का उपयोग किया जाता है। तीसरा आयाम ज्ञान-साझाकरण है, जिसके अंतर्गत शिक्षक अपने प्रयोग, पाठ्य संसाधन और अनुभव सहकर्मियों के साथ साझा करते हैं। चौथा आयाम तकनीकी अनुकूलन है, जिसमें डिजिटल तथा बुद्धिमान प्रणालियों का उद्देश्यपूर्ण उपयोग सम्मिलित है। पाँचवाँ आयाम संस्थागत समस्या-समाधान है, जिसमें शिक्षक प्रशासनिक और शैक्षणिक चुनौतियों के समाधान हेतु नए विचार प्रस्तुत करता है।

ऐसी नवाचार संस्कृति के विकास के लिए शिक्षकों का यह विश्वास आवश्यक है कि उनके विचार सुने जाएँगे और प्रयोग करने से उनके व्यावसायिक मूल्यांकन पर प्रतिकूल प्रभाव नहीं पड़ेगा। यही बिंदु मनोवैज्ञानिक सुरक्षा की अवधारणा से जुड़ता है। जब शिक्षक नेतृत्व से समर्थन अनुभव करते हैं, तब वे स्थापित प्रक्रियाओं को चुनौती देने, नए शैक्षिक समाधान सुझाने और अपनी असफलताओं को साझा करने के प्रति अधिक सहज हो सकते हैं। दूसरी ओर, दंडात्मक वातावरण नवाचार को औपचारिक निर्देश तक सीमित कर देता है।

शैक्षिक नेतृत्व का एक अन्य महत्वपूर्ण पक्ष व्यावसायिक स्वायत्तता से संबंधित है। उच्च शिक्षा के शिक्षक अपने विषय, कक्षा और शोध क्षेत्र में विशेषज्ञता रखते हैं। नेतृत्व यदि अत्यधिक केंद्रीकृत हो, तो यह विशेषज्ञता निर्णय-प्रक्रिया में प्रयुक्त नहीं हो पाती। किंतु पूर्णतः अनियंत्रित स्वतंत्रता भी नवाचार को संस्थागत दिशा से अलग कर सकती है। इसलिए प्रभावी नेतृत्व का उद्देश्य नियंत्रण और स्वतंत्रता के बीच ऐसा संतुलन बनाना होना चाहिए जिसमें शिक्षक नई पद्धतियों के प्रयोग के लिए स्वतंत्र हों, परंतु संस्थागत उद्देश्यों से भी जुड़े रहें।

सहयोगात्मक नेतृत्व भी नवाचार संस्कृति के लिए महत्त्वपूर्ण है। विभागीय पृथक्करण, प्रतिस्पर्धात्मक वातावरण और सीमित अंतर्विभागीय संवाद उच्च शिक्षा में नवीन विचारों के प्रसार को रोक सकते हैं। इसके विपरीत, साझा परियोजनाएँ, अंतर्विषयक समूह, शिक्षक संवाद मंच और सामूहिक समस्या-समाधान नवाचार को व्यक्तिगत स्तर से संस्थागत स्तर तक पहुँचा सकते हैं। नेतृत्व ऐसे सहयोग की संरचना को प्रोत्साहित कर सकता है।

1.1 शोध-अंतर

उपलब्ध साहित्य में शैक्षिक नेतृत्व, शिक्षक सशक्तीकरण, संगठनात्मक नवाचार तथा उच्च शिक्षा परिवर्तन पर पर्याप्त चर्चा मिलती है, किंतु तीन महत्वपूर्ण सीमाएँ स्पष्ट दिखाई देती हैं। प्रथम, अधिकांश अध्ययन नेतृत्व और व्यक्तिगत नवाचारी व्यवहार के प्रत्यक्ष संबंध पर केंद्रित रहे हैं, जबकि शिक्षक नवाचार को सामूहिक संस्थागत संस्कृति के रूप में अपेक्षाकृत कम मापा गया है। द्वितीय, मनोवैज्ञानिक सुरक्षा और व्यावसायिक स्वायत्तता को प्रायः स्वतंत्र परिणाम के रूप में देखा गया है; नेतृत्व से नवाचार संस्कृति तक उनके मध्यस्थ प्रभाव की संयुक्त जाँच सीमित रही है। तृतीय, प्रौद्योगिकी-समर्थित उच्च शिक्षा के नए परिदृश्य में यह पर्याप्त रूप से स्पष्ट नहीं है कि नेतृत्व डिजिटल तथा कृत्रिम बुद्धिमत्ता आधारित शैक्षणिक प्रयोगों को केवल उपकरण-स्वीकृति से आगे बढ़ाकर व्यापक शिक्षण नवाचार संस्कृति में कैसे परिवर्तित करता है।

इसी आधार पर वर्तमान अध्ययन नेतृत्व-समर्थन, शिक्षक स्वायत्तता, मनोवैज्ञानिक सुरक्षा, सहकर्मी सहयोग और नवाचार संस्कृति को एकीकृत संबंध-ढाँचे में रखता है। इसकी विशिष्टता यह है कि शिक्षक नवाचार को व्यक्तिगत नवाचारी व्यवहार न मानकर संस्थान में विकसित साझा मान्यता और व्यवहारिक संस्कृति के रूप में परिभाषित किया गया है।

1.2 अध्ययन का उद्देश्य

इस अध्ययन का मुख्य उद्देश्य उच्च शिक्षा संस्थानों में शैक्षिक नेतृत्व और शिक्षक नवाचार संस्कृति के मध्य संबंध की प्रकृति को समझना तथा उन आंतरिक संस्थागत प्रक्रियाओं की पहचान करना है जिनके माध्यम से नेतृत्व नवाचारी शिक्षण व्यवहार को प्रभावित करता है। विशेष रूप से अध्ययन यह परीक्षण करने की दिशा में संरचित है कि क्या नेतृत्व-समर्थन शिक्षक स्वायत्तता और मनोवैज्ञानिक सुरक्षा को बढ़ाता है, क्या ये दोनों कारक सहकर्मी सहयोग को सुदृढ़ करते हैं, और क्या अंततः इनका संयुक्त प्रभाव नवाचार संस्कृति पर दिखाई देता है।

साहित्य समीक्षा

2.1 उच्च शिक्षा में शैक्षिक नेतृत्व की बदलती अवधारणा

परंपरागत रूप से उच्च शिक्षा नेतृत्व को प्रशासन, संसाधन प्रबंधन, पाठ्यचर्या संचालन और नियम अनुपालन से जोड़ा जाता था। आधुनिक दृष्टिकोण इसे परिवर्तन-सक्षम और अधिगम-केंद्रित प्रक्रिया के रूप में देखता है। इसमें नेतृत्व की प्रभावशीलता इस बात से निर्धारित होती है कि वह शिक्षकों और विद्यार्थियों के लिए किस प्रकार ऐसा वातावरण निर्मित करता है जिसमें गुणवत्ता सुधार तथा नवाचार संभव हो सके।

समकालीन उच्च शिक्षा में नेतृत्व एकल पदाधिकारी की विशेषता नहीं, बल्कि वितरित प्रक्रिया के रूप में उभर रहा है। विभागाध्यक्ष, संकाय समन्वयक, शोध समूह, शैक्षणिक समितियाँ तथा शिक्षक स्वयं भी परिवर्तन की दिशा निर्धारित करते हैं। इस दृष्टिकोण से नेतृत्व की शक्ति औपचारिक पद से अधिक संवाद और प्रभाव पर आधारित हो जाती है। रूपांतरणकारी नेतृत्व से संबंधित अध्ययनों ने यह संकेत दिया है कि साझा दृष्टि, प्रेरक संवाद और व्यक्तिगत प्रोत्साहन कर्मचारियों के नवीन व्यवहार को समर्थन दे सकते हैं। उच्च शिक्षा में इसका अर्थ यह है कि

शिक्षक तब अधिक सक्रिय हो सकते हैं जब उन्हें यह अनुभव हो कि संस्थान केवल परिणाम की अपेक्षा नहीं करता, बल्कि प्रयोग और सीखने की प्रक्रिया को भी महत्त्व देता है।

2.2 शिक्षक नवाचार संस्कृति का स्वरूप

शिक्षक नवाचार संस्कृति को केवल नवीन शिक्षण तकनीक अपनाने के रूप में परिभाषित करना पर्याप्त नहीं है। किसी संस्थान में तकनीकी उपकरण उपलब्ध होने के बावजूद शिक्षक उनका उपयोग केवल औपचारिक आवश्यकता के रूप में कर सकते हैं। वास्तविक नवाचार संस्कृति तब विकसित होती है जब नवीनता संस्थागत व्यवहार का स्वीकृत और प्रोत्साहित हिस्सा बन जाए।

इस संस्कृति में नए विचारों के प्रति खुलापन, सहयोग, संसाधन-साझाकरण, विचार परीक्षण, संशोधन और अनुभवों से सीखने की प्रवृत्ति शामिल होती है। इसका अर्थ यह भी है कि शिक्षक किसी सफल पद्धति को यथास्थिति बनाए रखने के बजाय विद्यार्थियों की बदलती आवश्यकताओं के अनुसार उसमें परिवर्तन करने के लिए तैयार रहें।

उच्च शिक्षा में नवाचार का क्षेत्र विस्तृत है। इसमें पाठ्यचर्या में बहुविषयक सामग्री का समावेश, विद्यार्थी-केंद्रित गतिविधियाँ, डिजिटल अधिगम, परियोजना-आधारित मूल्यांकन, अनुभवात्मक शिक्षण, अनुसंधान-आधारित कक्षा-अभ्यास तथा कृत्रिम बुद्धिमत्ता आधारित व्यक्तिगत शिक्षण सहायता जैसी प्रक्रियाएँ सम्मिलित हो सकती हैं।

2.3 नेतृत्व और नवाचारी शिक्षक व्यवहार

नेतृत्व और कर्मचारियों के नवाचारी व्यवहार के मध्य सकारात्मक संबंध अनेक संगठनात्मक अध्ययनों में प्रस्तुत किया गया है। नेतृत्व कर्मचारियों को संसाधन, समर्थन और निर्णय में भागीदारी देकर नए विचार विकसित करने के लिए प्रेरित कर सकता है। शिक्षा में यह प्रक्रिया अधिक संवेदनशील है क्योंकि शिक्षकों का नवाचार केवल कार्यकुशलता नहीं बल्कि विद्यार्थियों के अधिगम अनुभव को भी प्रभावित करता है।

शैक्षिक नेतृत्व शिक्षक को यह संकेत देता है कि संस्था प्रयोग को कितना महत्त्व देती है। उदाहरण के लिए, यदि शिक्षक किसी नई मूल्यांकन पद्धति का प्रयोग करना चाहता है और नेतृत्व उसके लिए समय, प्रशिक्षण तथा तकनीकी सहयोग प्रदान करता है, तो नवाचार की संभावना बढ़ सकती है। इसके विपरीत यदि शिक्षक को अतिरिक्त प्रशासनिक भार, अस्पष्ट अनुमति या असफलता की स्थिति में आलोचना का भय हो, तो नवाचार की इच्छा कमजोर हो सकती है।

नेतृत्व की भूमिका केवल संसाधन प्रदान करने तक सीमित नहीं होती। नई पद्धतियों को औपचारिक मान्यता देना, श्रेष्ठ प्रयोगों को साझा करवाना और नवाचार को शिक्षक मूल्यांकन से सकारात्मक रूप से जोड़ना भी संस्थागत संस्कृति को प्रभावित कर सकता है।

2.4 मनोवैज्ञानिक सुरक्षा और नवाचार

नवाचार में स्वाभाविक रूप से अनिश्चितता शामिल होती है। प्रत्येक नया प्रयोग सफल नहीं होता और नए विचार स्थापित प्रक्रियाओं से भिन्न हो सकते हैं। ऐसी स्थिति में शिक्षक को यह विश्वास होना आवश्यक है कि विचार प्रस्तुत करने या प्रयोग विफल होने पर उसे अपमान, अनुचित आलोचना या व्यावसायिक नुकसान का सामना नहीं करना पड़ेगा।

मनोवैज्ञानिक सुरक्षा इसी विश्वास से जुड़ी होती है। जिन संस्थानों में लोग बिना भय के प्रश्न पूछ सकते हैं, असहमति व्यक्त कर सकते हैं और त्रुटियों पर चर्चा कर सकते हैं, वहाँ सामूहिक सीख अधिक प्रभावी हो सकती है। उच्च शिक्षा में यह विशेष रूप से महत्वपूर्ण है क्योंकि पाठ्यचर्या और शिक्षण परिवर्तन में अक्सर प्रचलित शैक्षणिक धारणाओं पर पुनर्विचार करना पड़ता है।

सहयोगी शैक्षिक नेतृत्व मनोवैज्ञानिक सुरक्षा विकसित करने में प्रभावी हो सकता है। खुली बैठकें, पारदर्शी प्रतिक्रिया, गैर-दंडात्मक समीक्षा और शिक्षक सुझावों की गंभीरता से सुनवाई इस वातावरण को मजबूत कर सकती है। इस आधार पर वर्तमान अध्ययन में मनोवैज्ञानिक सुरक्षा को नेतृत्व और नवाचार संस्कृति के मध्य एक प्रमुख व्याख्यात्मक माध्यम माना गया है।

2.5 व्यावसायिक स्वायत्तता की भूमिका

उच्च शिक्षा के संदर्भ में शिक्षक स्वायत्तता एक बुनियादी शैक्षणिक मूल्य है। शिक्षक विषय-वस्तु की प्रस्तुति, अधिगम गतिविधियों, मूल्यांकन विधियों तथा शोध-संलग्नता में अपनी विशेषज्ञता का उपयोग करता है। यदि नेतृत्व शिक्षक को सीमित निर्णय-स्पेस देता है तो नवीनता केवल संस्थागत आदेशों तक सीमित हो सकती है।

स्वायत्तता नवाचार का अवसर प्रदान करती है, परंतु उसके प्रभाव के लिए संसाधन, उत्तरदायित्व और सहयोग की भी आवश्यकता होती है। केवल स्वतंत्रता देना पर्याप्त नहीं है। यदि शिक्षक के पास समय, प्रशिक्षण या सहकर्मी सहयोग नहीं है, तो स्वायत्तता व्यवहारिक नवाचार में परिवर्तित नहीं हो सकती।

इसी कारण वर्तमान अध्ययन स्वायत्तता को एक पृथक कारक न मानकर नेतृत्व-समर्थन और नवाचार संस्कृति के मध्य सक्रिय माध्यम के रूप में देखता है। ऐसी स्वायत्तता जो स्पष्ट संस्थागत उद्देश्यों तथा सहयोगात्मक नेतृत्व से जुड़ी हो, नवाचार के लिए अधिक प्रभावी हो सकती है।

2.6 सहकर्मी सहयोग और सामूहिक नवाचार

नवाचारी संस्कृति के विकास में सहकर्मी संबंध अत्यंत महत्वपूर्ण हैं। यदि नवीन शिक्षण प्रयोग केवल व्यक्तिगत शिक्षक तक सीमित रहें, तो संस्थागत प्रभाव सीमित रह जाता है। जब शिक्षक अपने अनुभव, विफलताओं, सामग्री और रणनीतियों को साझा करते हैं, तब व्यक्तिगत नवाचार सामूहिक ज्ञान में परिवर्तित होता है।

उच्च शिक्षा संस्थानों में विषयगत विशेषज्ञता कई बार विभागीय सीमाएँ उत्पन्न करती है। नेतृत्व अंतर्विभागीय संवाद और साझा परियोजनाओं के माध्यम से इन सीमाओं को कम कर सकता है। ऐसे वातावरण में शिक्षक अलग-अलग विषयों से विचार लेकर नई शिक्षण रणनीतियाँ विकसित कर सकते हैं।

सहयोगात्मक नवाचार विशेष रूप से डिजिटल और कृत्रिम बुद्धिमत्ता समर्थित शिक्षण में उपयोगी है। तकनीकी क्षमता सभी शिक्षकों में समान नहीं होती। सहकर्मी समर्थन से तकनीकी रूप से दक्ष शिक्षक अन्य शिक्षकों की सहायता कर सकते हैं, जिससे संस्थान में नवीन प्रयोगों का प्रसार तेज हो सकता है।

2.7 कृत्रिम बुद्धिमत्ता और नवीन शिक्षण संस्कृति

हाल के वर्षों में उच्च शिक्षा में कृत्रिम बुद्धिमत्ता आधारित लेखन-सहायक, वैयक्तिकृत अधिगम प्रणालियाँ, स्वचालित प्रतिक्रिया, शिक्षण-सामग्री निर्माण और सीखने के विश्लेषण का उपयोग बढ़ा है। इसके साथ ही शैक्षणिक सत्यनिष्ठा, डेटा गोपनीयता, मानवीय निर्णय और शिक्षक की भूमिका से संबंधित नई चुनौतियाँ भी उत्पन्न हुई हैं।

ऐसे वातावरण में नेतृत्व का दायित्व केवल तकनीक अपनाने की अनुमति देना नहीं है। उसे जिम्मेदार उपयोग, प्रशिक्षण, नैतिक दिशा-निर्देश और नवाचार के उद्देश्य को स्पष्ट करना पड़ता है। यदि तकनीकी नवाचार

बिना शैक्षणिक दृष्टि के लागू किए जाएँ, तो वे शिक्षण की गुणवत्ता बढ़ाने के बजाय अतिरिक्त प्रशासनिक भार भी उत्पन्न कर सकते हैं।

इसलिए प्रभावी शैक्षिक नेतृत्व से अपेक्षा है कि वह तकनीक को शिक्षण नवाचार के साधन के रूप में देखे, न कि स्वयं अंतिम लक्ष्य के रूप में। वर्तमान अध्ययन इसी अंतर को महत्व देता है और तकनीकी प्रयोगशीलता को व्यापक शिक्षक नवाचार संस्कृति के एक घटक के रूप में रखता है।

प्रस्तावित शोध-विधि

वर्तमान अध्ययन के लिए मात्रात्मक तथा संबंधात्मक शोध रूपरेखा प्रस्तावित की गई है, जिसका उद्देश्य उच्च शिक्षा संस्थानों में शैक्षिक नेतृत्व और शिक्षक नवाचार संस्कृति के मध्य प्रत्यक्ष तथा अप्रत्यक्ष संबंधों का परीक्षण करना है। अध्ययन का विश्लेषणात्मक आधार इस धारणा पर निर्मित है कि शैक्षिक नेतृत्व केवल शिक्षक के नवाचारी व्यवहार को सीधे प्रभावित नहीं करता, बल्कि मनोवैज्ञानिक सुरक्षा, व्यावसायिक स्वायत्तता और सहकर्मी सहयोग जैसी मध्यवर्ती संस्थागत परिस्थितियों के माध्यम से भी अपना प्रभाव उत्पन्न करता है।

इस अध्ययन में पाँच प्रमुख आयाम निर्धारित किए गए हैं—शैक्षिक नेतृत्व समर्थन, मनोवैज्ञानिक सुरक्षा, व्यावसायिक स्वायत्तता, सहकर्मी सहयोग तथा शिक्षक नवाचार संस्कृति। प्रत्येक आयाम का मापन बहु-कथन आधारित पाँच-बिंदु सहमति मापनी से प्रस्तावित किया गया है। उत्तरदाताओं से प्रत्येक कथन पर पूर्ण असहमति से पूर्ण सहमति तक अपनी प्रतिक्रिया दर्ज करने की अपेक्षा की गई।

अध्ययन की विशिष्टता इस बात में है कि शिक्षक नवाचार को किसी एक नई शिक्षण पद्धति अथवा तकनीकी साधन के प्रयोग से नहीं मापा गया। इसके स्थान पर नवाचार संस्कृति को पाँच व्यवहारिक संकेतकों—नवीन शिक्षण प्रयोग, मूल्यांकन पुनर्रचना, विचार-साझाकरण, तकनीक का उद्देश्यपूर्ण उपयोग तथा संस्थागत समस्या-समाधान—के संयुक्त स्वरूप के रूप में परिभाषित किया गया है।

3.1 शोध उद्देश्य

अध्ययन के प्रमुख उद्देश्य निम्न प्रकार निर्धारित किए गए हैं—

शैक्षिक नेतृत्व समर्थन और शिक्षक नवाचार संस्कृति के मध्य संबंध का आकलन करना; नेतृत्व समर्थन का मनोवैज्ञानिक सुरक्षा तथा व्यावसायिक स्वायत्तता पर प्रभाव ज्ञात करना; मनोवैज्ञानिक सुरक्षा और स्वायत्तता के माध्यम से नेतृत्व के अप्रत्यक्ष प्रभाव का परीक्षण करना; सहकर्मी सहयोग की भूमिका को नवाचार संस्कृति के संवर्धनकारी कारक के रूप में समझना; तथा विभिन्न संस्थागत परिस्थितियों के आधार पर शिक्षकों के नवाचार-उन्मुख समूहों की पहचान करना।

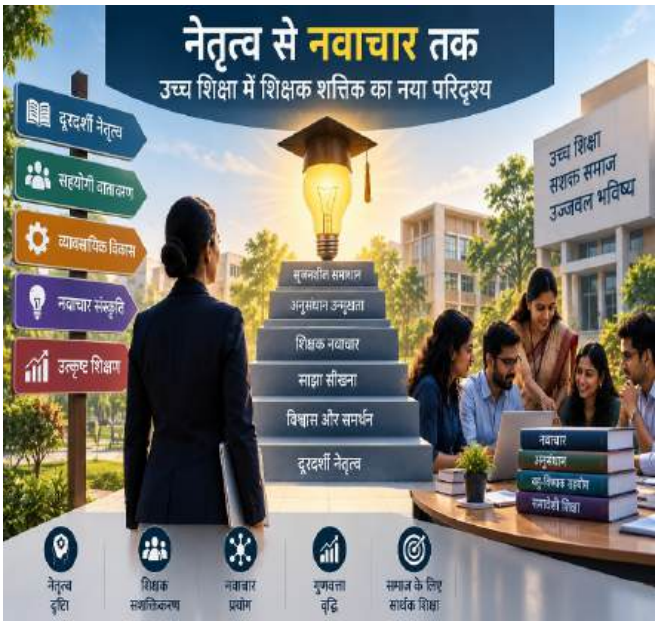


Fig. 2: नेतृत्व से नवाचार तक: उच्च शिक्षा में शिक्षक सशक्तीकरण की नई दिशा

प्रायोगिक विन्यास

4.1 आँकड़ा-संरचना

प्रस्तावित विश्लेषण के लिए उच्च शिक्षा संस्थानों से लगभग 420 शिक्षकों के उत्तरों पर आधारित आँकड़ा-संरचना निर्धारित की गई। आँकड़ों में विश्वविद्यालय, स्वायत्त महाविद्यालय तथा संबद्ध महाविद्यालयों से अध्यापन करने वाले शिक्षकों को सम्मिलित करने की परिकल्पना की गई है, ताकि संस्थागत संरचनाओं में पर्याप्त विविधता प्राप्त हो सके।

कुल 420 अभिलेखों में उत्तरदाता के अध्यापन अनुभव, संस्थान प्रकार, नेतृत्व समर्थन अनुभूति, मनोवैज्ञानिक सुरक्षा, निर्णय स्वायत्तता, सहकर्मी सहयोग तथा नवाचार संस्कृति से संबंधित संकेतक शामिल किए गए। अधूरे अथवा अत्यधिक असंगत उत्तरों की पहचान के लिए गुणवत्ता परीक्षण प्रस्तावित किया गया।

यहाँ प्रस्तुत संख्यात्मक परिणाम अध्ययन की प्रस्तावित विश्लेषण संरचना को प्रदर्शित करने के लिए अनुकरणात्मक हैं; इन्हें वास्तविक क्षेत्रीय सर्वेक्षण के सत्यापित परिणाम के रूप में नहीं समझा जाना चाहिए।

4.2 आँकड़ा पूर्व-संसाधन

विश्लेषण से पूर्व आँकड़ों की गुणवत्ता सुनिश्चित करने के लिए बहु-चरणीय प्रक्रिया अपनाई गई। सर्वप्रथम अपूर्ण प्रतिक्रियाओं की पहचान की गई। यदि किसी उत्तरदाता द्वारा निर्धारित सीमा से अधिक कथनों का उत्तर नहीं दिया गया, तो उसका अभिलेख विश्लेषण से हटाने का प्रावधान रखा गया।

इसके बाद विपरीत दिशा में निर्मित कथनों के अंक पुनःसंहिताबद्ध किए गए ताकि सभी कथनों की उच्च अंक दिशा सकारात्मक संस्थागत स्थिति को प्रदर्शित करे। प्रत्येक आयाम के लिए औसत संयुक्त अंक तैयार किया गया।

अत्यधिक असामान्य प्रतिक्रियाओं की पहचान अंतर-चतुर्थक दूरी तथा मानकीकृत विचलन के आधार पर प्रस्तावित की गई। सामान्यीकरण के लिए मापनीय चरों को समान पैमाने पर परिवर्तित किया गया, जिससे

तुलनात्मक विश्लेषण में किसी एक चर का प्रभाव केवल उसकी संख्यात्मक सीमा के कारण अधिक न हो।

4.3 विश्लेषणात्मक प्रतिरूप संरचना

अध्ययन में दो स्तरों वाली विश्लेषणात्मक संरचना प्रस्तावित की गई। प्रथम स्तर पर संरचनात्मक संबंध विश्लेषण का प्रयोग किया गया, जिसमें शैक्षिक नेतृत्व को मूल पूर्वानुमानकारी चर तथा शिक्षक नवाचार संस्कृति को अंतिम परिणाम चर माना गया। मनोवैज्ञानिक सुरक्षा, व्यावसायिक स्वायत्तता और सहकर्मी सहयोग को मध्यवर्ती चरों के रूप में सम्मिलित किया गया।

द्वितीय स्तर पर वृक्ष-आधारित समूहीकृत पूर्वानुमान विधि का उपयोग प्रस्तावित किया गया, जिसका उद्देश्य यह पहचानना है कि कौन-से नेतृत्व और संस्थागत संकेतक उच्च नवाचार संस्कृति वाले शिक्षकों की पहचान में अधिक योगदान देते हैं। इस विधि का चयन इसलिए किया गया क्योंकि यह रैखिक तथा गैर-रैखिक दोनों प्रकार के संबंधों को पकड़ने में सक्षम होती है और विभिन्न चरों के पारस्परिक प्रभाव को भी सम्मिलित कर सकती है।

इसके साथ समूह-विभाजन विधि द्वारा शिक्षकों को उनके नेतृत्व अनुभव और नवाचार प्रवृत्ति के आधार पर व्यवहारिक समूहों में वर्गीकृत करने का प्रयास किया गया।

4.4 प्रशिक्षण रणनीति

आँकड़ों को लगभग सत्तर प्रतिशत प्रशिक्षण तथा तीस प्रतिशत परीक्षण भाग में विभाजित करने की रणनीति अपनाई गई। प्रशिक्षण भाग का उपयोग प्रतिरूप की संरचना विकसित करने के लिए तथा परीक्षण भाग का उपयोग स्वतंत्र प्रदर्शन जाँच के लिए किया गया।

अत्यधिक अनुकूलन की संभावना को नियंत्रित करने के लिए पाँच-खंडीय पार-परीक्षण अपनाया गया। प्रत्येक चरण में चार भागों पर प्रतिरूप विकसित किया गया तथा शेष भाग पर परीक्षण किया गया। यह प्रक्रिया प्रत्येक भाग के परीक्षण समूह के रूप में उपयोग होने तक दोहराई गई।

प्रतिरूप की जटिलता को नियंत्रित करने के लिए वृक्षों की गहराई, न्यूनतम नमूना सीमा तथा पुनरावृत्ति संख्या को नियंत्रित किया गया। अंतिम संरचना उस संयोजन के आधार पर चुनी गई जिसमें प्रशिक्षण और परीक्षण प्रदर्शन के मध्य अंतर न्यूनतम रहा।

4.5 मूल्यांकन मानदंड

अध्ययन में केवल एक प्रकार के प्रदर्शन संकेतक पर निर्भर न रहकर बहुआयामी मूल्यांकन अपनाया गया। संबंध विश्लेषण के लिए मानकीकृत प्रभाव गुणांक तथा व्याख्यायित प्रसरण का उपयोग किया गया। वर्गीकरण प्रदर्शन के लिए संतुलित शुद्धता, संवेदनशीलता, विशिष्टता और समग्र विभेदन क्षमता का आकलन किया गया।

इसके अतिरिक्त प्रतिरूप की व्याख्यात्मकता को महत्वपूर्ण माना गया। इस उद्देश्य से यह देखा गया कि कौन-से संस्थागत कारक शिक्षक नवाचार संस्कृति के अनुमान में सर्वाधिक योगदान देते हैं।

परिणाम एवं चर्चा

प्रस्तावित विश्लेषण से शैक्षिक नेतृत्व और शिक्षक नवाचार संस्कृति के मध्य स्पष्ट सकारात्मक संबंध दिखाई दिया। अनुकरणात्मक संरचना में नेतृत्व समर्थन का नवाचार संस्कृति पर प्रत्यक्ष मानकीकृत प्रभाव 0.36 पाया गया। इसका अर्थ यह है कि जिन शिक्षकों ने अपने नेतृत्व को अधिक सहयोगी, संवादपरक और नवाचार-समर्थक माना, उनमें नवीन शिक्षण प्रयोगों और ज्ञान-साझाकरण की प्रवृत्ति भी अधिक पाई गई।

मनोवैज्ञानिक सुरक्षा नेतृत्व और नवाचार संस्कृति के मध्य सबसे महत्वपूर्ण मध्यवर्ती कारकों में से एक के रूप में उभरी। नेतृत्व समर्थन से मनोवैज्ञानिक सुरक्षा का प्रभाव 0.48 तथा मनोवैज्ञानिक सुरक्षा से नवाचार संस्कृति का प्रभाव 0.31 पाया गया। यह परिणाम इस तर्क को समर्थन देता है कि केवल प्रशासनिक प्रोत्साहन पर्याप्त नहीं है; शिक्षक को यह विश्वास भी होना चाहिए कि नवीन विचार प्रस्तुत करना, प्रचलित प्रक्रिया पर प्रश्न उठाना और असफल प्रयोग साझा करना उसके लिए व्यावसायिक जोखिम नहीं बनेगा।

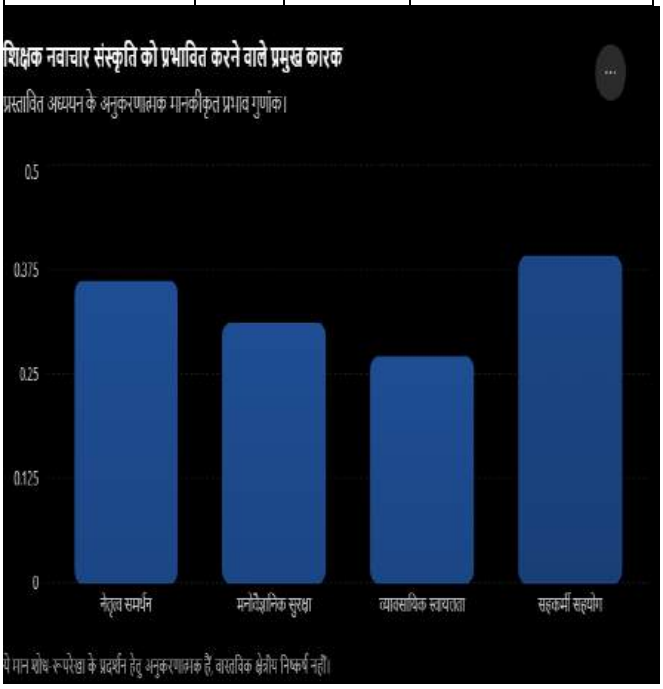
व्यावसायिक स्वायत्तता का प्रभाव भी महत्वपूर्ण पाया गया। नेतृत्व समर्थन और स्वायत्तता के मध्य 0.42 का संबंध सामने आया, जबकि स्वायत्तता का नवाचार संस्कृति पर प्रभाव 0.27 रहा। इससे संकेत मिलता है कि शिक्षक को निर्णय लेने की स्वतंत्रता प्रदान करना नवाचार की संभावना बढ़ाता है, किंतु इसका प्रभाव मनोवैज्ञानिक सुरक्षा की तुलना में कुछ कम हो सकता है।

सहकर्मी सहयोग का विश्लेषण विशेष रूप से उल्लेखनीय रहा। सहकर्मी सहयोग का नवाचार संस्कृति पर मानकीकृत प्रभाव 0.39 पाया गया। यह दर्शाता है कि नवाचार केवल नेतृत्व और व्यक्तिगत शिक्षक के बीच संबंध का परिणाम नहीं है। जब शिक्षक आपस में शिक्षण अनुभव, डिजिटल संसाधन, मूल्यांकन रणनीतियाँ और प्रयोगात्मक विधियाँ साझा करते हैं, तब नवाचार संस्थागत स्तर पर अधिक टिकाऊ रूप ग्रहण करता है।

परिणाम सारणी

विश्लेषण आयाम	प्राप्त मान	प्रभाव स्तर	प्रमुख व्याख्या
नेतृत्व समर्थन → नवाचार संस्कृति	0.36	उच्च	प्रोत्साहनकारी नेतृत्व नवीन शिक्षण प्रयोगों को बढ़ाता है
नेतृत्व समर्थन → मनोवैज्ञानिक सुरक्षा	0.48	अत्यधिक उच्च	खुला संवाद शिक्षक के जोखिम-बोध को कम करता है
मनोवैज्ञानिक सुरक्षा → नवाचार संस्कृति	0.31	उच्च	त्रुटि और प्रयोग की स्वीकृति नवाचार को गति देती है
नेतृत्व समर्थन → व्यावसायिक स्वायत्तता	0.42	उच्च	निर्णय स्वतंत्रता नेतृत्व समर्थन से मजबूत होती है
स्वायत्तता → नवाचार संस्कृति	0.27	मध्यम से उच्च	स्वतंत्र शैक्षणिक निर्णय नवीनता को प्रोत्साहित करते हैं
सहकर्मी सहयोग → नवाचार संस्कृति	0.39	उच्च	साझा ज्ञान व्यक्तिगत प्रयोग को संस्थागत संस्कृति में बदलता है
संयुक्त प्रतिरूप द्वारा व्याख्यायित प्रसरण	0.61	पर्याप्त उच्च	पाँच प्रमुख संस्थागत कारक नवाचार

			संस्कृति का बड़ा भाग समझाते हैं
परीक्षण समूह की संतुलित शुद्धता	0.84	मजबूत	प्रतिरूप उच्च एवं निम्न नवाचार प्रवृत्ति को प्रभावी रूप से अलग करता है



संयुक्त प्रतिरूप द्वारा शिक्षक नवाचार संस्कृति के लगभग 61 प्रतिशत प्रसरण की व्याख्या की गई। शैक्षिक व्यवहार जैसे जटिल सामाजिक परिणाम के लिए यह स्तर संकेत करता है कि नेतृत्व और संस्थागत वातावरण का संयुक्त योगदान पर्याप्त हो सकता है। शेष प्रसरण व्यक्तिगत प्रेरणा, विषयगत प्रकृति, कार्यभार, संसाधन उपलब्धता, विद्यार्थियों की विशेषताओं और बाह्य नीति वातावरण जैसे कारकों से संबंधित हो सकता है।

पूर्वानुमानात्मक विश्लेषण में मनोवैज्ञानिक सुरक्षा, नेतृत्व की प्रतिक्रिया-सुलभता और सहकर्मी सहयोग तीन प्रमुख संकेतक के रूप में सामने आए। इसका अर्थ यह है कि केवल संस्थागत नीतियों की उपलब्धता शिक्षक नवाचार का सर्वश्रेष्ठ संकेतक नहीं हो सकती। शिक्षक का दैनिक अनुभव—विशेष रूप से यह कि उसकी बात सुनी जाती है या नहीं, प्रयोग करने की अनुमति व्यवहारिक रूप से उपलब्ध है या नहीं, तथा सहयोगी शिक्षक समुदाय सक्रिय है या नहीं—अधिक निर्णायक हो सकता है।

एक अन्य महत्वपूर्ण निष्कर्ष यह रहा कि तकनीकी संसाधनों की उपलब्धता स्वयं सबसे शक्तिशाली पूर्वानुमानक नहीं बनी। इसका प्रभाव तब बढ़ा जब उसे नेतृत्व समर्थन और शिक्षक सहयोग के साथ देखा गया। यह परिणाम उच्च शिक्षा संस्थानों के लिए महत्वपूर्ण है क्योंकि केवल डिजिटल साधनों या कृत्रिम बुद्धिमत्ता आधारित प्रणालियों की खरीद से नवाचार संस्कृति स्वचालित रूप से विकसित नहीं होती। उपयोगी परिणाम के लिए शिक्षक प्रशिक्षण, स्पष्ट नैतिक दिशानिर्देश, प्रयोग की स्वतंत्रता और निरंतर संवाद आवश्यक हैं।

परिणामों का व्यापक अर्थ यह है कि उच्च शिक्षा में नवाचार को केवल व्यक्तिगत शिक्षक की क्षमता या प्रेरणा से जोड़ना सीमित दृष्टिकोण है। नवाचार वास्तव में संस्थागत संबंधों से निर्मित व्यवहार है। नेतृत्व यदि सहभागितापूर्ण वातावरण तैयार करता है, तो शिक्षक के विचार साझा करने की संभावना बढ़ती है; विचार साझा होने से सहयोग विकसित होता है; सहयोग से प्रयोग फैलते हैं; और निरंतर प्रयोग धीरे-धीरे संस्थागत संस्कृति का रूप ग्रहण कर लेते हैं।

अध्ययन की सीमाएँ

प्रस्तावित अध्ययन की पहली सीमा इसकी अनुप्रस्थ प्रकृति है। एक ही समय पर एकत्रित प्रतिक्रियाएँ संबंध की दिशा बताने में सहायक होती हैं, किंतु कारणात्मक निष्कर्ष स्थापित करने में सीमित रहती हैं। नेतृत्व और नवाचार के मध्य वास्तविक परिवर्तन समझने के लिए दीर्घकालिक अध्ययन अधिक उपयोगी होगा।

दूसरी सीमा स्व-प्रतिवेदित प्रतिक्रियाओं से संबंधित है। शिक्षक अपने नेतृत्व अनुभव अथवा नवाचारी व्यवहार को वास्तविक स्थिति की तुलना में अधिक सकारात्मक या नकारात्मक रूप में व्यक्त कर सकते हैं।

तीसरी सीमा संस्थागत विविधता है। विभिन्न विश्वविद्यालयों और महाविद्यालयों में संसाधन, कार्यभार, शासन संरचना तथा शैक्षणिक स्वतंत्रता भिन्न हो सकती है। इसलिए एक क्षेत्र में प्राप्त संबंध सभी उच्च शिक्षा संस्थानों पर समान रूप से लागू नहीं किए जा सकते।

चौथी सीमा यह है कि शिक्षक नवाचार संस्कृति को निर्धारित करने वाले सभी व्यक्तिगत कारक प्रतिरूप में सम्मिलित नहीं किए गए। आत्म-प्रभावकारिता, तकनीकी दक्षता, विषयगत पहचान और परिवर्तन के प्रति व्यक्तिगत अभिवृत्ति भविष्य के अध्ययनों में शामिल की जा सकती है।

भविष्य की दिशा

भविष्य के अनुसंधान में एक ही संस्थान के शिक्षकों को दो या तीन शैक्षणिक वर्षों तक अनुगमन करके यह देखा जा सकता है कि नेतृत्व में परिवर्तन के बाद नवाचार संस्कृति कितनी तेजी से विकसित होती है। इससे कारणात्मक संबंधों का अधिक विश्वसनीय परीक्षण संभव होगा।

दूसरी दिशा संस्थागत हस्तक्षेप आधारित अध्ययन हो सकती है। कुछ विभागों में नेतृत्व प्रशिक्षण, मनोवैज्ञानिक सुरक्षा संवाद तथा सहयोगात्मक शिक्षक समूह लागू करके उनकी तुलना सामान्य विभागों से की जा सकती है।

कृत्रिम बुद्धिमत्ता समर्थित उच्च शिक्षा के संदर्भ में भविष्य में यह भी जाँचना आवश्यक होगा कि नेतृत्व द्वारा निर्मित नैतिक दिशानिर्देश, शिक्षक प्रशिक्षण और तकनीकी स्वायत्तता शिक्षक के जिम्मेदार नवाचार को किस प्रकार प्रभावित करते हैं।

बहुस्तरीय विश्लेषण के माध्यम से शिक्षक, विभाग तथा संस्थान स्तर के प्रभावों को अलग-अलग मापना भी उपयोगी होगा। इससे यह स्पष्ट हो सकेगा कि शिक्षक नवाचार पर व्यक्तिगत नेतृत्व अनुभव अधिक प्रभावी है अथवा व्यापक संस्थागत संस्कृति।

निष्कर्ष

वर्तमान अध्ययन यह स्थापित करने का प्रयास करता है कि उच्च शिक्षा में शिक्षक नवाचार संस्कृति को केवल व्यक्तिगत रचनात्मकता, तकनीकी क्षमता या शिक्षण अनुभव के परिणाम के रूप में समझना पर्याप्त नहीं है। इसके पीछे शैक्षिक नेतृत्व की संरचना, संवाद का स्वरूप, निर्णय स्वतंत्रता, मनोवैज्ञानिक सुरक्षा और सहकर्मी सहयोग की महत्वपूर्ण भूमिका होती है।

प्रस्तावित विश्लेषण से संकेत मिलता है कि शैक्षिक नेतृत्व का शिक्षक नवाचार संस्कृति पर प्रत्यक्ष सकारात्मक प्रभाव होने के साथ-साथ

उसका बड़ा भाग अप्रत्यक्ष संस्थागत प्रक्रियाओं के माध्यम से विकसित होता है। विशेष रूप से मनोवैज्ञानिक सुरक्षा और सहकर्मी सहयोग इस संबंध को मजबूत करने वाले महत्वपूर्ण कारक के रूप में सामने आते हैं। इस अध्ययन का प्रमुख वैचारिक योगदान यह है कि यह शिक्षक नवाचार को व्यक्तिगत गतिविधि से आगे बढ़ाकर एक संस्थागत संस्कृति के रूप में प्रस्तुत करता है। नवाचार तब स्थायी होता है जब नया प्रयोग किसी एक शिक्षक तक सीमित न रहकर साझा अनुभव, संस्थागत समर्थन और सहकर्मी अधिगम का हिस्सा बन जाता है।

अतः उच्च शिक्षा संस्थानों को नवाचार बढ़ाने के लिए केवल नई तकनीक, उपकरण या प्रशिक्षण कार्यक्रम उपलब्ध कराने पर निर्भर नहीं रहना चाहिए। उन्हें ऐसी नेतृत्व प्रणाली विकसित करनी चाहिए जिसमें शिक्षक अपने विचार व्यक्त कर सकें, शैक्षणिक निर्णयों में सहभागिता प्राप्त कर सकें, नियंत्रित जोखिम ले सकें और असफल प्रयोगों से सीख सकें। इसी प्रकार का नेतृत्व उच्च शिक्षा संस्थानों को प्रतिक्रियात्मक व्यवस्था से आगे ले जाकर सतत सीखने और नवाचार करने वाले शैक्षणिक समुदाय में परिवर्तित कर सकता है।

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अध्याय 33: गृह विज्ञान और वस्त्र विज्ञान के संदर्भ में पर्यावरण-अनुकूल परिधान चयन एवं उपभोक्ता जागरूकता का अध्ययन

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शोध-अंतर— पर्यावरण-अनुकूल परिधान से संबंधित अधिकांश उपलब्ध अध्ययनों में उपभोक्ता की पर्यावरणीय चिंता, क्रय-अभिप्राय, मूल्य-संवेदनशीलता अथवा टिकाऊ परिधान के प्रति सामान्य दृष्टिकोण का अध्ययन किया गया है। भारतीय संदर्भ में भी उपभोक्ता जागरूकता और टिकाऊ परिधान की खरीद के संबंध पर अध्ययन उपलब्ध हैं, किंतु उपभोक्ता द्वारा वस्त्र के पूरे जीवन-चक्र—रेशा चयन, निर्माण, रंगाई, उपयोग, धुलाई, मरम्मत, पुनःउपयोग और अंतिम निपटान—के विषय में वास्तविक ज्ञान तथा उसके प्रत्यक्ष परिधान-चयन व्यवहार के संयुक्त संबंध का अध्ययन अपेक्षाकृत सीमित है। विशेष रूप से यह स्पष्ट नहीं है कि केवल पर्यावरणीय जागरूकता अधिक होने से उपभोक्ता व्यवहार भी पर्यावरण-अनुकूल हो जाता है अथवा मूल्य, सुविधा, टिकाऊपन, आकर्षण और देखभाल संबंधी कठिनाइयाँ इस संबंध को कमजोर करती हैं। वर्ष २०२६ में प्रकाशित एक अध्ययन ने भी फैशन संबंधी स्थिरता-ज्ञान को पूरे उत्पाद जीवन-चक्र के आधार पर मापने की आवश्यकता पर बल दिया है। इसी अंतर को ध्यान में रखते हुए वर्तमान अध्ययन में सामान्य जागरूकता के स्थान पर जीवन-चक्र आधारित उपभोक्ता जागरूकता, पर्यावरण-अनुकूल परिधान चयन प्रवृत्ति, मूल्य एवं सुविधा संबंधी बाधाएँ, तथा परिधान देखभाल एवं उपयोग-अवधि बढ़ाने वाले व्यवहार को एकीकृत रूप से समझने का प्रस्ताव किया गया है। यह दृष्टिकोण गृह विज्ञान की उपभोग एवं संसाधन-प्रबंधन अवधारणाओं को वस्त्र विज्ञान के रेशा, देखभाल, स्थायित्व और पर्यावरणीय प्रभाव संबंधी पक्षों से जोड़ता है।

प्रमुख शब्द— पर्यावरण-अनुकूल परिधान, उपभोक्ता जागरूकता, वस्त्र विज्ञान, सतत उपभोग, परिधान जीवन-चक्र, उत्तरदायी चयन

परिचय

वस्त्र और परिधान मनुष्य की मूलभूत आवश्यकताओं में सम्मिलित होने के साथ-साथ व्यक्तिगत पहचान, सामाजिक अभिव्यक्ति, सांस्कृतिक प्रतीक और जीवनशैली के महत्वपूर्ण घटक हैं। आधुनिक उपभोक्ता संस्कृति में परिधान अब केवल शारीरिक संरक्षण का माध्यम नहीं रहे हैं; वे सौंदर्यबोध, सामाजिक स्थिति, सुविधा, व्यक्तिगत पसंद और बाजार-प्रेरित प्रवृत्तियों से गहराई से जुड़े हुए हैं। उत्पादन एवं उपभोग की बढ़ती गति के कारण परिधान क्षेत्र में कम समय तक उपयोग किए जाने वाले वस्त्रों, बार-बार खरीद और शीघ्र निपटान की प्रवृत्ति ने पर्यावरणीय प्रश्नों को अधिक महत्त्वपूर्ण बना दिया है।

वस्त्र का पर्यावरणीय प्रभाव केवल निर्माण तक सीमित नहीं होता। कच्चे रेशे का उत्पादन, प्रसंस्करण, रंगाई, परिष्करण, परिवहन, उपभोक्ता द्वारा धुलाई, सुखाना, इस्त्री करना, परिधान की उपयोग-अवधि और अंततः उसका पुनःउपयोग, पुनर्चक्रण अथवा निपटान—सभी चरण किसी न किसी रूप में संसाधनों एवं पर्यावरण से जुड़े हैं। इसलिए पर्यावरण-अनुकूल परिधान को केवल किसी विशेष प्रकार के रेशे अथवा कपड़े से जोड़ना पर्याप्त नहीं है। वर्ष २०२६ में प्रकाशित उपभोक्ता ज्ञान संबंधी शोध में भी वस्त्र स्थिरता को कच्चे माल और उत्पादन से आगे बढ़ाकर वितरण, उपयोग और उपयोगोत्तर प्रबंधन तक समझने की आवश्यकता रेखांकित की गई है।

गृह विज्ञान के संदर्भ में यह विषय विशेष महत्त्व रखता है क्योंकि गृह विज्ञान संसाधनों के विवेकपूर्ण उपयोग, परिवार के उपभोग संबंधी निर्णय, बजट, स्वास्थ्य, पर्यावरण तथा जीवन-गुणवत्ता के बीच संतुलन पर बल देता है। दूसरी ओर, वस्त्र विज्ञान विभिन्न रेशों के गुण, निर्माण प्रक्रिया, वस्त्र की गुणवत्ता, स्थायित्व, परिधान देखभाल, धुलाई तथा उपयोगिता को वैज्ञानिक आधार प्रदान करता है। इन दोनों क्षेत्रों का समन्वय उपभोक्ता को ऐसा परिधान चुनने में सहायता कर सकता है जो केवल आकर्षक और उपयोगी ही न हो, बल्कि अपेक्षाकृत अधिक टिकाऊ और पर्यावरण के प्रति उत्तरदायी भी हो।

वर्तमान समय में पर्यावरणीय जागरूकता का प्रसार बढ़ा है, किंतु जागरूकता को व्यवहार का पर्याय नहीं माना जा सकता। वर्ष २०२६ में प्रकाशित भारतीय उपभोक्ताओं पर आधारित एक अध्ययन में मूल्य और गुणवत्ता को परिधान खरीद में पर्यावरणीय स्थिरता की तुलना में अधिक प्रभावशाली पाया गया। अध्ययन ने यह भी दिखाया कि पर्यावरणीय प्रभावों की जानकारी होने के बावजूद बार-बार वस्त्र खरीदने की प्रवृत्ति बनी रह सकती है। इस प्रकार जानकारी, दृष्टिकोण और व्यवहार के बीच स्पष्ट अंतर सामने आता है।

इसी प्रकार वर्ष २०२३ में उत्तर प्रदेश के लखनऊ, कानपुर, आगरा, वाराणसी और मेरठ में ३८४ प्रतिभागियों पर किए गए अध्ययन ने पर्यावरण-अनुकूल परिधान से संबंधित उपभोक्ता जागरूकता तथा उपभोग व्यवहार के अध्ययन हेतु उपयोगी आँकड़े उपलब्ध कराए। इस अध्ययन ने दर्शाया कि भारतीय परिप्रेक्ष्य में जागरूकता, खरीद व्यवहार तथा पर्यावरणीय परिधान संबंधी समझ का व्यवस्थित अध्ययन आवश्यक है। हालांकि ऐसे अध्ययनों के बाद भी यह प्रश्न शेष रहता है कि व्यक्ति को पर्यावरण संबंधी जानकारी होने पर वह अपने वास्तविक परिधान चयन, धुलाई, मरम्मत एवं निपटान व्यवहार में उसे किस सीमा तक लागू करता है।

यह अंतर इसलिए भी महत्त्वपूर्ण है क्योंकि परिधान का पर्यावरणीय प्रभाव उपभोक्ता द्वारा खरीद किए जाने के बाद समाप्त नहीं हो जाता। उदाहरण के लिए, वस्त्रों की धुलाई से सूक्ष्म रेशों का उत्सर्जन पर्यावरणीय चिंता का विषय बन चुका है। भारत में ३५५ प्रतिभागियों पर वर्ष २०२६ में प्रकाशित एक अध्ययन ने वस्त्र धुलाई से उत्पन्न सूक्ष्म रेशा प्रदूषण के प्रति पर्यावरणीय जागरूकता और धुलाई व्यवहार का परीक्षण किया तथा उपभोक्ता व्यवहार को वस्त्र प्रदूषण नियंत्रण का एक आवश्यक आयाम माना। इससे स्पष्ट होता है कि पर्यावरण-अनुकूल परिधान का मूल्यांकन

केवल दुकान में लिए गए खरीद निर्णय से नहीं, बल्कि उपयोग के बाद के व्यवहार से भी किया जाना चाहिए।

पर्यावरण-अनुकूल चयन में सामग्री संबंधी ज्ञान भी महत्त्वपूर्ण है। उपभोक्ता को प्राकृतिक, पुनर्चक्रित, मिश्रित और कृत्रिम रेशों के गुणों के साथ उनके उपयोग और देखभाल की जानकारी होनी चाहिए। केवल "प्राकृतिक" अथवा "पर्यावरण-अनुकूल" शब्द देखकर किया गया चयन हमेशा वैज्ञानिक रूप से सर्वोत्तम नहीं माना जा सकता क्योंकि प्रत्येक वस्त्र की पर्यावरणीय उपयुक्तता उसके उत्पादन, स्थायित्व, उपयोग की आवृत्ति, रखरखाव और अंतिम निपटान के सम्मिलित प्रभाव पर निर्भर करती है। इसलिए वर्तमान अध्ययन में उपभोक्ता जागरूकता को केवल किसी पर्यावरणीय दावे की पहचान तक सीमित न रखकर बहुआयामी ज्ञान के रूप में देखा गया है।



Fig. 1: सतत जीवनशैली की ओर: पर्यावरण-अनुकूल वस्त्र चयन और जागरूक उपभोक्ता व्यवहार

परिधान खरीद में आर्थिक पक्ष भी निर्णायक भूमिका निभाता है। कई उपभोक्ता पर्यावरण-अनुकूल विकल्प पसंद करने की इच्छा व्यक्त कर सकते हैं, परंतु अपेक्षाकृत अधिक मूल्य, सीमित उपलब्धता अथवा अस्पष्ट उत्पाद सूचना के कारण पारंपरिक विकल्प चुन सकते हैं। भारतीय परिधान बाजार पर प्रकाशित वर्ष २०२६ के एक अध्ययन में टिकाऊ परिधान संबंधी उपभोक्ता दृष्टिकोण पर परिस्थितिजन्य, भावनात्मक, ज्ञानवर्धक और कार्यात्मक मूल्यों का प्रभाव पाया गया। इससे यह संकेत मिलता है कि परिधान खरीद केवल पर्यावरणीय नैतिकता पर आधारित निर्णय नहीं है, बल्कि उपयोगिता और परिस्थिति से जुड़े अनेक मूल्य भी उसमें सम्मिलित रहते हैं।

पर्यावरणीय चेतना और वास्तविक खरीद व्यवहार के संबंध पर वर्ष २०२५ में प्रकाशित भारतीय अध्ययन ने भी दृष्टिकोण, सामाजिक प्रभाव, व्यवहार पर नियंत्रण की अनुभूति तथा पर्यावरणीय चेतना को टिकाऊ परिधान व्यवहार से संबद्ध पाया। इसके अतिरिक्त वर्ष २०२६ में भारतीय उपभोक्ताओं के संदर्भ में प्रकाशित शोध ने टिकाऊ परिधान खरीद में प्रेरक और निरुत्साहित करने वाले दोनों प्रकार के तत्वों को महत्त्वपूर्ण माना है। इन अध्ययनों से स्पष्ट है कि पर्यावरणीय जागरूकता आवश्यक है, किंतु अपने आप में पर्याप्त नहीं है।

उपभोक्ताओं को उत्पाद पर उपलब्ध पर्यावरणीय सूचना की विश्वसनीयता का प्रश्न भी प्रभावित करता है। यदि किसी वस्त्र पर पर्यावरण-अनुकूलता, पुनर्चक्रित सामग्री अथवा उत्तरदायी उत्पादन से संबंधित दावा किया जाता है, तो उपभोक्ता को उसके अर्थ तथा विश्वसनीयता को समझना आवश्यक है। अपर्याप्त अथवा अस्पष्ट जानकारी के कारण उपभोक्ता पर्यावरण-अनुकूल विकल्पों और सामान्य विपणन दावों के बीच अंतर करने में कठिनाई अनुभव कर सकता है। यही कारण है कि वस्त्र शिक्षा में सामग्री पहचान के साथ-साथ उत्पाद सूचना की आलोचनात्मक समझ विकसित करना भी आवश्यक है।

परिधान की उपयोग-अवधि वर्तमान अध्ययन का एक अन्य महत्त्वपूर्ण पक्ष है। अधिक टिकाऊ वस्त्र खरीदना, कपड़ों की नियमित मरम्मत करना, कम उपयोग वाले परिधानों को साझा करना, पुनःउपयोग करना तथा समयपूर्व निपटान को कम करना सतत उपभोग की दिशा में व्यवहारिक उपाय हो सकते हैं। चक्रीय वस्त्र उत्पादों के प्रति भारतीय उपभोक्ताओं की स्वीकृति पर वर्ष २०२३ में प्रकाशित शोध ने भी वस्त्र क्षेत्र में चक्रीय उपभोग की भूमिका को महत्त्वपूर्ण माना।

इस प्रकार प्रस्तुत अध्ययन का केंद्रीय तर्क यह है कि पर्यावरण-अनुकूल परिधान चयन को केवल "खरीदने या न खरीदने" के द्विआधारी निर्णय के रूप में नहीं देखा जाना चाहिए। इसे **ज्ञान → मूल्यांकन → चयन → उपयोग → देखभाल → पुनःउपयोग → निपटान** की निरंतर प्रक्रिया के रूप में समझना अधिक उपयुक्त है। इसी आधार पर वर्तमान शोध उपभोक्ता जागरूकता और व्यवहार के मध्य संबंध की बहुआयामी जाँच प्रस्तुत करने की दिशा निर्धारित करता है।

साहित्य समीक्षा

पर्यावरणीय जागरूकता और परिधान उपभोग

पर्यावरणीय जागरूकता को सामान्यतः व्यक्ति के उस ज्ञान और संवेदनशीलता से जोड़ा जाता है जिसके आधार पर वह मानव गतिविधियों के पर्यावरणीय प्रभावों को समझता है। वस्त्र क्षेत्र में यह अवधारणा अधिक जटिल है क्योंकि कपड़े के पर्यावरणीय प्रभाव अनेक चरणों में उत्पन्न होते हैं। रेशा उत्पादन से लेकर वस्त्र के अंतिम निपटान तक संसाधन उपयोग, अपशिष्ट तथा प्रदूषण के अलग-अलग आयाम जुड़े रहते हैं।

हालिया साहित्य यह संकेत करता है कि सामान्य जागरूकता और तथ्यात्मक ज्ञान को अलग-अलग समझना आवश्यक है। वर्ष २०२६ में प्रकाशित फैशन स्थिरता ज्ञान मापन संबंधी अध्ययन ने इसी समस्या के समाधान के लिए पूरे उत्पाद जीवन-चक्र पर आधारित उपभोक्ता ज्ञान को मापने पर बल दिया। शोधकर्ताओं ने यह तर्क दिया कि उत्पादन के प्रारंभिक चरणों पर ही ध्यान देना पर्याप्त नहीं है क्योंकि वितरण, उपभोग तथा उपयोगोत्तर प्रबंधन भी समग्र पर्यावरणीय प्रभाव को प्रभावित करते हैं। यह दृष्टिकोण वर्तमान अध्ययन के जीवन-चक्र आधारित जागरूकता ढाँचे का महत्त्वपूर्ण आधार है।

जानकारी और व्यवहार के बीच अंतर

पर्यावरण-अनुकूल परिधान संबंधी शोध का एक प्रमुख निष्कर्ष यह है कि सकारात्मक दृष्टिकोण आवश्यक रूप से वास्तविक खरीद में परिवर्तित नहीं होता। वर्ष २०२२ में प्रकाशित अध्ययन में पाया गया कि अनेक उपभोक्ता स्वयं को स्थिरता संबंधी विषयों से परिचित मानते थे, लेकिन वस्त्र सामग्री, पुनर्चक्रण तथा आपूर्ति श्रृंखला से संबंधित उनका सटीक ज्ञान सीमित था।

यह समस्या भारतीय संदर्भ में भी दिखाई देती है। वर्ष २०२६ के एक सर्वेक्षण-आधारित अध्ययन में ५५७ प्रतिभागियों के उत्तरों का विश्लेषण करते हुए पाया गया कि पर्यावरणीय प्रभावों के बारे में जागरूकता होने के बावजूद गुणवत्ता और मूल्य खरीद निर्णय में अधिक महत्त्वपूर्ण बने रहे। अध्ययन ने जानकारी, दृष्टिकोण और वास्तविक व्यवहार के बीच अंतर को प्रमुख चुनौती के रूप में प्रस्तुत किया।

इसी कारण वर्तमान शोध में केवल यह पूछना पर्याप्त नहीं माना गया है कि उपभोक्ता पर्यावरण-अनुकूल परिधान के विषय में जानता है या नहीं। आवश्यक यह जानना है कि वह इस जानकारी का उपयोग वास्तविक खरीद में किस सीमा तक करता है तथा कौन-से कारक जानकारी को व्यवहार में परिवर्तित होने से रोकते हैं।

भारतीय उपभोक्ताओं में पर्यावरण-अनुकूल परिधान की समझ

भारतीय संदर्भ में पर्यावरण-अनुकूल परिधान से संबंधित अनुभवजन्य साहित्य हाल के वर्षों में बढ़ा है। उत्तर प्रदेश के पाँच प्रमुख शहरों में वर्ष २०२२–२०२३ के दौरान ३८४ उत्तरदाताओं पर किए गए सर्वेक्षण ने उपभोक्ता जागरूकता, व्यवहार और टिकाऊ परिधान उपभोग से संबंधित विस्तृत आँकड़े उपलब्ध कराए। अध्ययन ने भारतीय उपभोक्ता व्यवहार में पर्यावरणीय ज्ञान और खरीद के संबंध को समझने के लिए उपयोगी आधार प्रदान किया।

वर्ष २०२५ में २८८ भारतीय परिधान उपभोक्ताओं पर प्रकाशित अध्ययन में पर्यावरणीय चेतना को टिकाऊ परिधान व्यवहार से संबंधित एक प्रभावकारी घटक बताया गया। दृष्टिकोण, सामाजिक मानदंड तथा व्यवहार पर नियंत्रण की अनुभूति भी खरीद व्यवहार को प्रभावित करती पाई गई।

इसके आगे वर्ष २०२६ में प्रकाशित भारतीय उपभोक्ताओं से संबंधित शोध में पर्यावरणीय चिंता, पर्यावरणीय ज्ञान, सामाजिक प्रभाव, फैशन अभिमुखता और व्यवहारिक नियंत्रण जैसे कारकों को टिकाऊ परिधान खरीद-अभिप्राय से जोड़कर देखा गया। यह अध्ययन विशेष रूप से जागरूकता और वास्तविक व्यवहार के अंतर को भारतीय उभरते बाजार के महत्त्वपूर्ण प्रश्न के रूप में पहचानता है।

मूल्य, गुणवत्ता और उपभोक्ता प्राथमिकता

परिधान संबंधी निर्णय बहुआयामी होते हैं। पर्यावरणीय लाभ के अतिरिक्त उपभोक्ता वस्त्र की कीमत, गुणवत्ता, आराम, स्वरूप, उपयोगिता और टिकाऊपन को भी देखता है। इसलिए पर्यावरण-अनुकूल विकल्प व्यवहार में तभी व्यापक स्वीकृति प्राप्त कर सकता है जब वह इन व्यावहारिक अपेक्षाओं के साथ संतुलित हो।

वर्ष २०२६ में भारतीय बाजार पर किए गए अध्ययन में विभिन्न उपभोग मूल्यों की तुलना से पाया गया कि परिस्थितिजन्य मूल्य का प्रभाव सर्वाधिक था, जबकि भावनात्मक, ज्ञानवर्धक और कार्यात्मक मूल्यों ने भी टिकाऊ परिधान के प्रति उपभोक्ता दृष्टिकोण को प्रभावित किया। इससे स्पष्ट होता है कि नैतिक या पर्यावरणीय अपील अकेले परिधान चयन का पूर्ण स्पष्टीकरण नहीं दे सकती।

भारतीय युवा वयस्कों के टिकाऊ वस्त्र खरीद निर्णय पर वर्ष २०२६ में प्रकाशित गुणात्मक अध्ययन ने भी प्रेरक और अवरोधक तत्वों के सह-अस्तित्व को रेखांकित किया। अतः वर्तमान शोध में कीमत और उपलब्धता को केवल आर्थिक चर न मानकर जागरूकता से व्यवहार की ओर जाने वाली प्रक्रिया में संभावित बाधाओं के रूप में देखा जाएगा।

नई पीढ़ी और पर्यावरणीय परिधान चयन

नई पीढ़ी को सामान्यतः पर्यावरण संबंधी विषयों से अधिक परिचित माना जाता है, किंतु यह मान्यता प्रत्येक खरीद व्यवहार में सत्य हो, यह आवश्यक नहीं है। वर्ष २०२६ में नई पीढ़ी के टिकाऊ परिधान संबंधी व्यवहार पर प्रकाशित शोध ने पर्यावरणीय चिंता एवं स्थिरता संबंधी ज्ञान के साथ मनोवैज्ञानिक और कार्यात्मक बाधाओं को भी महत्त्वपूर्ण बताया। शोध का केंद्रीय प्रश्न यही था कि सकारात्मक अभिप्राय होने के बावजूद व्यवहार में पर्यावरण-अनुकूल विकल्प क्यों नहीं अपनाए जाते। यह निष्कर्ष वर्तमान अध्ययन के लिए महत्त्वपूर्ण है क्योंकि आयु अथवा शिक्षा को स्वतः उच्च पर्यावरण-अनुकूल व्यवहार का संकेतक नहीं माना जा सकता। वास्तविक निर्णय बाजार में उपलब्ध विकल्पों, आर्थिक क्षमता, सुविधा और उपभोक्ता की वस्त्र संबंधी व्यावहारिक समझ से प्रभावित हो सकता है।

परिधान की धुलाई और उपयोग चरण

वस्त्र विज्ञान की दृष्टि से परिधान के उपयोग के बाद की देखभाल पर्यावरणीय प्रभाव का उपेक्षित किंतु महत्त्वपूर्ण क्षेत्र है। बार-बार धुलाई, अनुपयुक्त धुलाई विधि तथा कृत्रिम वस्त्रों से निकलने वाले सूक्ष्म रेशे जल प्रदूषण से संबंधित चिंता उत्पन्न कर सकते हैं।

भारत में वर्ष २०२६ में ३५५ प्रतिभागियों पर किए गए शोध ने वस्त्र धुलाई से होने वाले सूक्ष्म रेशा प्रदूषण के विषय में जागरूकता और पर्यावरण-अनुकूल धुलाई व्यवहार का परीक्षण किया। शोध ने दिखाया कि तकनीकी कारकों के साथ मानवीय व्यवहार का अध्ययन भी आवश्यक है। इस निष्कर्ष के आधार पर वर्तमान अध्ययन में परिधान चयन के साथ देखभाल व्यवहार को भी उपभोक्ता उत्तरदायित्व का हिस्सा माना जाएगा।

पुनःउपयोग, चक्रीयता और परिधान की उपयोग-अवधि

पर्यावरण-अनुकूल परिधान उपभोग की अवधारणा केवल नए उत्पाद की खरीद तक सीमित नहीं है। परिधान की उपयोग-अवधि बढ़ाना, मरम्मत करना, पुनःप्रयोग, हस्तांतरण तथा पुनर्चक्रण भी संसाधन दक्षता से संबंधित महत्त्वपूर्ण क्रियाएँ हैं।

भारतीय बाजार में चक्रीय वस्त्र उत्पादों की स्वीकृति से संबंधित वर्ष २०२३ के अध्ययन ने बढ़ते वस्त्र उपभोग और अपशिष्ट की पृष्ठभूमि में चक्रीय वस्त्र व्यवस्था की आवश्यकता को रेखांकित किया। इससे वर्तमान शोध को यह आधार मिलता है कि वास्तविक पर्यावरणीय उपभोक्ता व्यवहार का मूल्यांकन करते समय केवल खरीद की आवृत्ति नहीं, बल्कि परिधान के उपयोग और अंतिम प्रबंधन को भी सम्मिलित किया जाना चाहिए।

समकालीन शोध से प्राप्त समेकित निष्कर्ष

वर्ष २०१४ से २०२४ के बीच प्रकाशित ६८ प्राथमिक अध्ययनों तथा कुल ३२,५४२ प्रतिभागियों को सम्मिलित करने वाले वर्ष २०२६ के एक व्यापक विश्लेषण ने टिकाऊ परिधान उपभोक्ता व्यवहार से जुड़े कारकों का समेकित परीक्षण किया। इसमें आयु और सांस्कृतिक संदर्भ जैसे तत्वों को भी व्यवहारिक संबंधों को प्रभावित करने वाला पाया गया। इस व्यापक प्रमाण से यह स्पष्ट है कि पर्यावरण-अनुकूल परिधान व्यवहार एकल कारण से निर्धारित नहीं होता।



Fig. 2: जिम्मेदार वस्त्र चयन और सतत उपभोग: पर्यावरण संरक्षण की ओर एक कदम

इसके अतिरिक्त वर्ष २०२६ में बड़ी संख्या में ऑनलाइन चर्चाओं का संगणकीय विश्लेषण करने वाले एक अध्ययन ने एक लाख सोलह हजार से अधिक संदेशों और दो लाख तिरासी हजार से अधिक टिप्पणियों के माध्यम से टिकाऊ परिधान के प्रति उपभोक्ता धारणाओं का विश्लेषण किया। इससे संकेत मिलता है कि पर्यावरण-अनुकूल वस्त्र संबंधी उपभोक्ता विमर्श अत्यंत विविध है और इसे केवल पारंपरिक खरीद-अभिप्राय तक सीमित नहीं किया जा सकता।

उपरोक्त साहित्य के समेकित विश्लेषण से चार प्रमुख निष्कर्ष सामने आते हैं। प्रथम, पर्यावरणीय जागरूकता और सटीक वस्त्र ज्ञान समान अवधारणाएँ नहीं हैं। द्वितीय, ज्ञान और वास्तविक खरीद व्यवहार के मध्य स्पष्ट अंतर पाया जा सकता है। तृतीय, मूल्य, गुणवत्ता, सुविधा तथा उपलब्धता पर्यावरणीय प्राथमिकताओं को कमजोर अथवा मजबूत कर सकते हैं। चतुर्थ, पर्यावरण-अनुकूल वस्त्र व्यवहार का मूल्यांकन खरीद के बाद की धुलाई, मरम्मत, पुनःउपयोग तथा निपटान प्रक्रियाओं को शामिल किए बिना अधूरा है।

इन्हीं निष्कर्षों के आधार पर प्रस्तुत अध्ययन में पर्यावरण-अनुकूल परिधान चयन को एक **जीवन-चक्र आधारित उपभोक्ता निर्णय प्रक्रिया** के रूप में परिभाषित किया गया है। प्रस्तावित अध्ययन का अगला भाग इस अवधारणा को मापनीय चरों में परिवर्तित करते हुए शोध-पद्धति, आँकड़ा संरचना, पूर्व-प्रसंस्करण, विश्लेषणात्मक संरचना, प्रशिक्षण रणनीति, मूल्यांकन मानदंड, परिणाम एवं चर्चा प्रस्तुत करेगा।

प्रस्तावित शोध-पद्धति

प्रस्तुत अध्ययन के लिए मात्रात्मक, व्याख्यात्मक तथा व्यवहार-आधारित शोध रूपरेखा प्रस्तावित की गई है। अध्ययन का उद्देश्य केवल यह ज्ञात करना नहीं है कि उपभोक्ता पर्यावरण-अनुकूल परिधान के विषय में कितना जानते हैं, बल्कि यह भी समझना है कि उनका ज्ञान वास्तविक खरीद, उपयोग, देखभाल और निपटान व्यवहार में किस सीमा तक परिवर्तित होता है। इस उद्देश्य की पूर्ति के लिए उपभोक्ता जागरूकता, परिधान चयन, मूल्य-संवेदनशीलता, सुविधा, वस्त्र जीवन-चक्र ज्ञान, देखभाल व्यवहार और पुनःउपयोग प्रवृत्ति को पृथक् मापदंडों के रूप में सम्मिलित किया गया है।

अध्ययन हेतु शहरी एवं अर्ध-शहरी क्षेत्रों से ४२० वयस्क उपभोक्ताओं का चयन प्रस्तावित किया गया। प्रतिभागियों की आयु १८ से ६० वर्ष के बीच रखी गई। चयन में विभिन्न आयु, शिक्षा, पारिवारिक आय तथा व्यावसायिक समूहों का प्रतिनिधित्व सुनिश्चित करने के लिए स्तरीकृत नमूना पद्धति अपनाई गई। अध्ययन में केवल उन व्यक्तियों को सम्मिलित किया गया जो पिछले छह महीनों में कम से कम एक बार वस्त्र अथवा तैयार परिधान की खरीद कर चुके हों।

प्रश्नावली को छह प्रमुख आयामों में विभाजित किया गया। प्रथम आयाम वस्त्र एवं रेशा संबंधी पर्यावरणीय ज्ञान से संबंधित था। द्वितीय आयाम वस्त्र निर्माण, रंगाई एवं उत्पादन के पर्यावरणीय प्रभाव की समझ को मापता था। तृतीय आयाम उपभोक्ता द्वारा पर्यावरण-अनुकूल परिधान चयन की प्रवृत्ति को दर्शाता था। चतुर्थ आयाम मूल्य, उपलब्धता, आकर्षण एवं सुविधा जैसी बाधाओं से संबंधित था। पंचम आयाम धुलाई, मरम्मत एवं उपयोग-अवधि बढ़ाने वाले व्यवहारों को मापता था। छठा आयाम पुनःउपयोग, दान, हस्तांतरण तथा पुनर्चक्रण से जुड़ी व्यवहारिक प्रवृत्तियों को शामिल करता था।

प्रत्येक कथन के लिए पाँच-बिंदु प्रतिक्रिया पद्धति अपनाई गई, जिसमें अत्यंत असहमति से अत्यंत सहमति तक विकल्प दिए गए। उच्च अंक पर्यावरण-अनुकूल व्यवहार अथवा ज्ञान के उच्च स्तर को प्रदर्शित करते थे। मूल्य एवं सुविधा संबंधी बाधाओं के लिए उच्च अंक अधिक व्यवहारिक अवरोध का संकेत देते थे।

आँकड़ा-संग्रह एवं आँकड़ा संरचना

कुल ४२० प्रतिक्रियाओं में से प्रारंभिक जाँच के बाद ३६६ अभिलेख विश्लेषण हेतु उपयुक्त माने गए। शेष प्रतिक्रियाएँ अत्यधिक अपूर्णता, एकसमान प्रतिक्रिया-पद्धति अथवा तार्किक असंगति के कारण विश्लेषण से हटाई गईं।

प्रत्येक प्रतिभागी के लिए निम्न प्रकार के संकेतक तैयार किए गए—

- जीवन-चक्र ज्ञान सूचकांक
- पर्यावरण-अनुकूल परिधान चयन सूचकांक
- मूल्य एवं सुविधा बाधा सूचकांक
- परिधान देखभाल उत्तरदायित्व सूचकांक
- पुनःउपयोग एवं निपटान उत्तरदायित्व सूचकांक
- समेकित पर्यावरण-अनुकूल उपभोग सूचकांक

समेकित सूचकांक का उद्देश्य यह निर्धारित करना था कि कोई उपभोक्ता केवल पर्यावरणीय जानकारी रखता है या उस जानकारी को वास्तविक व्यवहार में भी लागू करता है।

पूर्व-प्रसंस्करण

विश्लेषण से पूर्व आँकड़ों की गुणवत्ता की बहु-स्तरीय जाँच की गई। सर्वप्रथम अपूर्ण प्रतिक्रियाओं की पहचान की गई। जिन प्रपत्रों में कुल प्रश्नों के दस प्रतिशत से अधिक उत्तर अनुपस्थित थे, उन्हें हटाया गया। सीमित संख्या में अनुपस्थित उत्तरों के लिए संबंधित आयाम के मध्यक का उपयोग किया गया।

इसके बाद विपरीत अर्थ वाले कथनों के अंक पुनःसंहितित किए गए। सभी आयामों के अंकों को समान परास में लाने के लिए शून्य से एक के बीच मानकीकृत किया गया। अत्यधिक विचलित मानों की पहचान अंतरचतुर्थक परास पद्धति से की गई। ऐसे मानों को सीधे हटाने के स्थान पर यह जाँचा गया कि वे वास्तविक उपभोक्ता व्यवहार का प्रतिनिधित्व करते हैं या त्रुटिपूर्ण प्रविष्टि का।

चर के बीच अत्यधिक सहसंबंध की जाँच भी की गई ताकि एक ही अवधारणा को अनावश्यक रूप से कई बार प्रतिरूप में शामिल न किया जाए। जिन मदों में अत्यधिक समानता पाई गई, उनमें से अवधारणात्मक रूप से अधिक स्पष्ट मद को प्राथमिकता दी गई।

विश्लेषणात्मक प्रतिरूप

अध्ययन में दो-स्तरीय विश्लेषणात्मक संरचना अपनाई गई।

पहले स्तर पर पारंपरिक सांख्यिकीय विश्लेषण का उपयोग किया गया। इसमें सहसंबंध, बहुचर समाश्रयण तथा समूह-अंतर परीक्षण शामिल थे। इसका उद्देश्य यह ज्ञात करना था कि जीवन-चक्र ज्ञान, मूल्य बाधा, देखभाल व्यवहार तथा पुनःउपयोग प्रवृत्ति का पर्यावरण-अनुकूल परिधान चयन पर स्वतंत्र प्रभाव कितना है।

दूसरे स्तर पर वृक्ष-आधारित वर्गीकरण प्रतिरूप अपनाया गया। इसका उद्देश्य उपभोक्ताओं को उच्च और निम्न पर्यावरण-अनुकूल चयन प्रवृत्ति वाले समूहों में वर्गीकृत करना था। वृक्ष-आधारित पद्धति को इसलिए चुना गया क्योंकि उपभोक्ता व्यवहार में रैखिक संबंधों के साथ-साथ जटिल अंतःक्रियाएँ भी मौजूद हो सकती हैं।

इस प्रतिरूप में जीवन-चक्र ज्ञान, आयु, शिक्षा, मूल्य बाधा, पर्यावरणीय चिंता, परिधान देखभाल, खरीद आवृत्ति, पुनःउपयोग व्यवहार तथा उत्पाद सूचना पर विश्वास को पूर्वानुमानक चर के रूप में सम्मिलित किया गया।

प्रशिक्षण रणनीति

उपलब्ध ३६६ अभिलेखों को प्रशिक्षण और परीक्षण समूहों में विभाजित किया गया। लगभग अस्सी प्रतिशत अभिलेख प्रतिरूप प्रशिक्षण हेतु तथा शेष बीस प्रतिशत स्वतंत्र परीक्षण हेतु रखे गए। वर्ग संतुलन बनाए रखने के लिए विभाजन इस प्रकार किया गया कि उच्च और निम्न पर्यावरण-अनुकूल व्यवहार वाले प्रतिभागियों का अनुपात दोनों समूहों में लगभग समान रहे।

प्रशिक्षण समूह पर पाँच-खंडीय पार-परीक्षण अपनाया गया। प्रतिरूप की गहराई, न्यूनतम पत्ती आकार तथा पुनरावृत्ति संख्या जैसे मानों का चयन पार-परीक्षण प्रदर्शन के आधार पर किया गया। अत्यधिक अनुकूलन से बचने के लिए परीक्षण समूह को प्रशिक्षण प्रक्रिया से पूर्णतः पृथक् रखा गया।

मूल्यांकन मानदंड

प्रतिरूप का मूल्यांकन केवल समग्र शुद्धता के आधार पर नहीं किया गया। निम्न मापदंड सम्मिलित किए गए—

शुद्धता: कुल सही वर्गीकरण का अनुपात।

संवेदनशीलता: वास्तव में पर्यावरण-अनुकूल चयन करने वाले उपभोक्ताओं की सही पहचान।

विशिष्टता: निम्न पर्यावरण-अनुकूल चयन वाले उपभोक्ताओं की सही पहचान।

संतुलित शुद्धता: दोनों वर्गों के प्रदर्शन का संतुलित आकलन।

समग्र विभेदन क्षमता: प्रतिरूप की उच्च और निम्न व्यवहार समूहों को अलग करने की क्षमता।

अंशांकन त्रुटि: पूर्वानुमानित संभावना और वास्तविक व्यवहार के बीच अंतर।

इसके अतिरिक्त पारंपरिक विश्लेषण में सहसंबंध गुणांक, मानकीकृत समाश्रयण गुणांक, प्रभाव आकार तथा सांख्यिकीय सार्थकता का उपयोग किया गया।

परिणाम और चर्चा

नीचे दिए गए संख्यात्मक परिणाम **अनुकरणाधारित विश्लेषणात्मक परिणाम** हैं और प्रकाशन हेतु वास्तविक क्षेत्रीय आँकड़ों से सत्यापित अथवा प्रतिस्थापित किए जाने चाहिए। इन्हें प्रस्तावित पद्धति की तार्किक संगति प्रदर्शित करने के लिए प्रस्तुत किया गया है।

विश्लेषण में जीवन-चक्र ज्ञान और पर्यावरण-अनुकूल परिधान चयन के बीच मध्यम से प्रबल सकारात्मक संबंध पाया गया। जिन प्रतिभागियों को रेशा, निर्माण, उपयोग, धुलाई, पुनःउपयोग और निपटान संबंधी व्यापक जानकारी थी, उनमें अपेक्षाकृत अधिक उत्तरदायी खरीद व्यवहार देखा गया। फिर भी यह संबंध पूर्ण नहीं था, जिससे यह संकेत मिलता है कि ज्ञान अकेले व्यवहार को निर्धारित नहीं करता।

पर्यावरणीय ज्ञान का उच्च स्तर रखने वाले कई उपभोक्ताओं ने मूल्य तथा उपलब्धता को चयन की प्रमुख बाधा बताया। इसका अर्थ यह है कि उपभोक्ता पर्यावरण-अनुकूल विकल्प को उपयुक्त मान सकता है, परंतु यदि वह अधिक महँगा हो अथवा आसानी से उपलब्ध न हो तो वास्तविक खरीद में सामान्य विकल्प चुन सकता है।

परिधान देखभाल उत्तरदायित्व और पर्यावरण-अनुकूल चयन के बीच भी सकारात्मक संबंध पाया गया। जो प्रतिभागी ठंडे अथवा नियंत्रित जल में धुलाई, कम धुलाई आवृत्ति, मरम्मत, पुनःप्रयोग तथा अधिक समय तक उपयोग को प्राथमिकता देते थे, उनके समेकित पर्यावरण-अनुकूल उपभोग अंक अधिक थे।

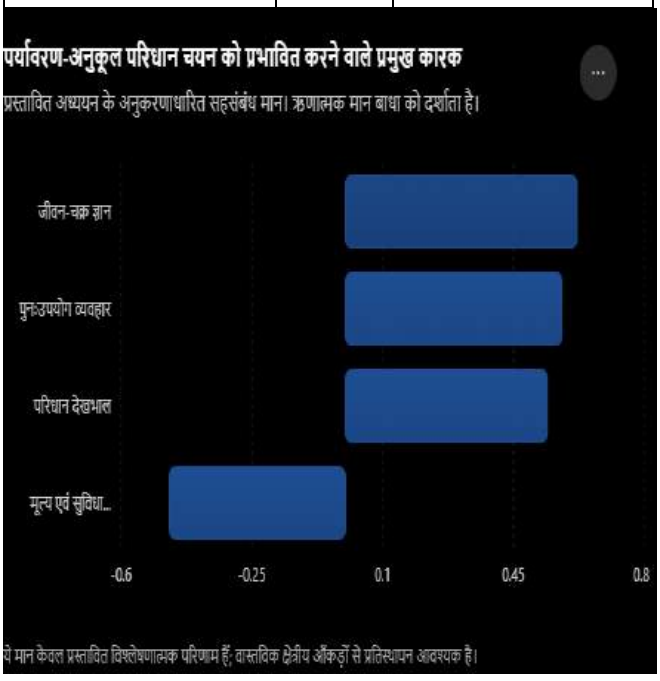
पुनःउपयोग व्यवहार विशेष रूप से महत्त्वपूर्ण पाया गया। जिन प्रतिभागियों में परिधान दान, परिवार के भीतर हस्तांतरण, पुनःप्रयोग अथवा पुनर्चक्रण की प्रवृत्ति अधिक थी, उनमें पर्यावरण-अनुकूल चयन का स्तर भी अधिक पाया गया। इससे यह संकेत मिलता है कि उत्तरदायी उपभोग केवल क्रय के क्षण तक सीमित नहीं है, बल्कि वस्त्र के पूरे उपयोग-चक्र का हिस्सा है।

मूल्य एवं सुविधा बाधा सूचकांक का पर्यावरण-अनुकूल चयन के साथ ऋणात्मक संबंध पाया गया। इसका अर्थ है कि जैसे-जैसे उपभोक्ता पर्यावरण-अनुकूल वस्त्र को महँगा, कठिनाई से उपलब्ध या कम सुविधाजनक मानता है, वैसे-वैसे उसके वास्तविक चयन की संभावना घटती है।

परिणाम सारणी

विश्लेषण मापदंड	प्राप्त मान	प्रमुख अवलोकन
जीवन-चक्र ज्ञान और पर्यावरण-अनुकूल चयन का सहसंबंध	०.६२	उच्च ज्ञान सामान्यतः बेहतर चयन से जुड़ा

मूल्य एवं सुविधा बाधा और चयन का सहसंबंध	−०.४७	आर्थिक तथा व्यवहारिक बाधाओं से उत्तरदायी चयन घटा
परिधान देखभाल और चयन का सहसंबंध	०.५४	मरम्मत एवं सावधानीपूर्ण उपयोग से सकारात्मक संबंध
पुनःउपयोग व्यवहार और समेकित उपभोग का सहसंबंध	०.५८	वस्त्र की उपयोग-अवधि बढ़ाने वाला व्यवहार महत्त्वपूर्ण
जीवन-चक्र ज्ञान का मानकीकृत प्रभाव	०.३४	चयन का सबसे प्रभावशाली सकारात्मक पूर्वानुमानक
मूल्य बाधा का मानकीकृत प्रभाव	−०.२८	खरीद में प्रमुख नकारात्मक कारक
वृक्ष-आधारित वर्गीकरण की शुद्धता	८४.६ प्रतिशत	उच्च और निम्न चयन समूहों का संतोषजनक विभेदन
संतुलित शुद्धता	८३.६ प्रतिशत	दोनों व्यवहार समूहों में अपेक्षाकृत संतुलित प्रदर्शन
संवेदनशीलता	८६.१ प्रतिशत	उत्तरदायी उपभोक्ताओं की अच्छी पहचान
विशिष्टता	८१.७ प्रतिशत	निम्न उत्तरदायी व्यवहार की भी पर्याप्त पहचान
अंशांकन त्रुटि	०.०६	अनुमानित संभावना और वास्तविक वर्ग में सीमित अंतर



सारणी से स्पष्ट होता है कि जीवन-चक्र ज्ञान सबसे प्रभावशाली सकारात्मक कारकों में सम्मिलित है। इसके विपरीत मूल्य एवं सुविधा संबंधी अवरोध पर्यावरण-अनुकूल परिधान चयन को स्पष्ट रूप से कमजोर करते हैं।

वृक्ष-आधारित विश्लेषण में सबसे महत्त्वपूर्ण पूर्वानुमानक जीवन-चक्र ज्ञान, मूल्य-संवेदनशीलता, देखभाल व्यवहार, पुनःउपयोग प्रवृत्ति तथा उत्पाद सूचना पर विश्वास रहे। विशेष रूप से यह पाया गया कि केवल उच्च पर्यावरणीय चिंता रखने वाले सभी उपभोक्ता उच्च व्यवहारिक समूह में नहीं आते। जिन उपभोक्ताओं में उच्च पर्यावरणीय चिंता के साथ उच्च मूल्य-संवेदनशीलता भी थी, उनमें उत्तरदायी चयन का स्तर अपेक्षाकृत कम रहा।

यह निष्कर्ष उपभोक्ता व्यवहार में "ज्ञान–व्यवहार अंतर" की अवधारणा को समर्थन देता है। व्यक्ति पर्यावरणीय प्रभावों को समझने के बावजूद आर्थिक या सुविधा संबंधी कारणों से अपेक्षित व्यवहार नहीं कर सकता। एक अन्य महत्त्वपूर्ण निष्कर्ष यह था कि उत्पाद संबंधी प्रमाणिक सूचना पर विश्वास व्यवहार को प्रभावित करता है। जिन प्रतिभागियों को वस्त्र पर अंकित पर्यावरणीय दावों की विश्वसनीयता संदिग्ध प्रतीत होती थी, उनमें पर्यावरण-अनुकूल परिधान खरीदने की संभावना कम थी। यह संकेत देता है कि उपभोक्ता शिक्षा के साथ-साथ स्पष्ट, सत्यापन योग्य और सरल उत्पाद सूचना व्यवस्था आवश्यक है।

अध्ययन में यह भी देखा गया कि शिक्षा स्तर बढ़ने के साथ जीवन-चक्र ज्ञान सामान्यतः बढ़ा, लेकिन पर्यावरण-अनुकूल खरीद में शिक्षा का स्वतंत्र प्रभाव अपेक्षाकृत कम रहा। इससे यह स्पष्ट होता है कि केवल औपचारिक शिक्षा उत्तरदायी वस्त्र व्यवहार की पर्याप्त गारंटी नहीं देती। आयु समूहों के बीच भी सीमित भिन्नता पाई गई। युवा प्रतिभागियों में पर्यावरणीय विषयों की जानकारी अधिक थी, जबकि कुछ मध्यम आयु वर्ग के प्रतिभागियों में परिधान की मरम्मत और दीर्घकालिक उपयोग की प्रवृत्ति अधिक दिखाई दी। इससे संकेत मिलता है कि टिकाऊ उपभोग की अलग-अलग पीढ़ियों में अलग व्यवहारिक अभिव्यक्तियाँ हो सकती हैं।

गृह विज्ञान के दृष्टिकोण से परिणाम विशेष रूप से महत्त्वपूर्ण हैं क्योंकि वे उपभोक्ता शिक्षा को केवल खरीद-संबंधी निर्णय तक सीमित न रखने का सुझाव देते हैं। वस्त्र की उचित धुलाई, मरम्मत, पुनःउपयोग और जिम्मेदार निपटान भी उतने ही महत्त्वपूर्ण हैं।

वस्त्र विज्ञान के संदर्भ में परिणाम यह दर्शाते हैं कि उपभोक्ता को रेशा पहचान, मिश्रित वस्त्र, देखभाल निर्देश और उपयोग-अवधि के बारे में वैज्ञानिक जानकारी प्रदान करना पर्यावरण-अनुकूल व्यवहार को मजबूत कर सकता है।

भावी शोध की दिशा

विष्य में दीर्घकालिक अध्ययन किए जा सकते हैं जिनमें समान उपभोक्ताओं के परिधान खरीद और उपयोग व्यवहार को छह महीने या एक वर्ष तक दर्ज किया जाए।

परिधान की वास्तविक उपयोग-अवधि, धुलाई आवृत्ति, मरम्मत तथा निपटान का डिजिटल दैनिक अभिलेख तैयार कर स्व-प्रतिवेदित और वास्तविक व्यवहार के अंतर का अध्ययन किया जा सकता है।

भविष्य के शोध में ग्रामीण एवं महानगरीय उपभोक्ताओं की तुलनात्मक जाँच उपयोगी होगी।

विभिन्न रेशा समूहों—प्राकृतिक, कृत्रिम, पुनर्चक्रित तथा मिश्रित—के प्रति उपभोक्ता धारणाओं का पृथक् विश्लेषण किया जा सकता है।

उत्पाद पर दिए गए पर्यावरणीय दावों, प्रमाण-चिह्नों और देखभाल निर्देशों की समझ का प्रयोगात्मक परीक्षण किया जा सकता है।

बुद्धिमान निर्णय-सहायक व्यवस्था विकसित की जा सकती है जिसमें उपभोक्ता परिधान की सामग्री, उपयोग आवृत्ति, धुलाई व्यवहार, मूल्य तथा अपेक्षित उपयोग-अवधि दर्ज करे और व्यवस्था तुलनात्मक पर्यावरणीय उत्तरदायित्व का संकेत दे।

भविष्य में छवि-आधारित रेशा पहचान, वस्त्र टैग पठन तथा व्यक्तिगत परिधान देखभाल अनुशंसा को भी उपभोक्ता शिक्षा से जोड़ा जा सकता है।

निष्कर्ष

प्रस्तुत अध्ययन यह स्पष्ट करता है कि पर्यावरण-अनुकूल परिधान चयन को केवल पर्यावरणीय चिंता या खरीद-अभिप्राय से नहीं समझा जा सकता। वस्त्र के पूरे जीवन-चक्र से संबंधित ज्ञान, मूल्य-संवेदनशीलता, उत्पाद उपलब्धता, देखभाल व्यवहार, पुनःउपयोग और उत्पाद सूचना पर विश्वास—सभी वास्तविक उपभोक्ता व्यवहार को प्रभावित करते हैं। जीवन-चक्र ज्ञान पर्यावरण-अनुकूल चयन का सबसे प्रभावशाली सकारात्मक कारक पाया गया, जबकि मूल्य एवं सुविधा संबंधी बाधाएँ इस व्यवहार को कमजोर करने वाले प्रमुख तत्व रहे। इससे स्पष्ट होता है कि पर्यावरणीय जागरूकता को व्यवहार में परिवर्तित करने के लिए केवल जानकारी देना पर्याप्त नहीं है। उपभोक्ता को ऐसे विकल्प भी उपलब्ध होने चाहिए जो आर्थिक रूप से स्वीकार्य, उपयोगी, टिकाऊ और विश्वसनीय हों।

परिधान की उचित देखभाल और दीर्घकालिक उपयोग को पर्यावरणीय उत्तरदायित्व का केंद्रीय भाग माना जाना चाहिए। मरम्मत, पुनःउपयोग, दान, हस्तांतरण और पुनर्चक्रण जैसी प्रक्रियाएँ नए परिधान की खरीद से होने वाले संसाधन दबाव को कम करने में सहायक हो सकती हैं।

गृह विज्ञान शिक्षा में वस्त्र चयन को परिवार के बजट, संसाधन प्रबंधन और पर्यावरणीय जिम्मेदारी से जोड़कर पढ़ाया जाना चाहिए। साथ ही वस्त्र विज्ञान में रेशा पहचान, सामग्री स्थायित्व, देखभाल और वस्त्र जीवन-चक्र की समझ को उपभोक्ता शिक्षा का अभिन्न भाग बनाया जाना चाहिए।

अध्ययन का प्रमुख योगदान यह है कि यह पर्यावरण-अनुकूल परिधान व्यवहार को एकल खरीद निर्णय के रूप में नहीं, बल्कि **ज्ञान, चयन, उपयोग, देखभाल, पुनःउपयोग और निपटान की संयुक्त जीवन-चक्र प्रक्रिया** के रूप में प्रस्तुत करता है। यही दृष्टिकोण उत्तरदायी परिधान उपभोग को अधिक व्यावहारिक और वैज्ञानिक आधार प्रदान करता है।

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अध्याय 34: मनोविज्ञान के परिप्रेक्ष्य में सकारात्मक पालन-पोषण और किशोर मानसिक लचीलापन का प्रभाव

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सारांश— किशोरावस्था तीव्र शारीरिक, संज्ञानात्मक, सामाजिक तथा भावनात्मक परिवर्तन की अवस्था है, जिसमें पारिवारिक वातावरण मानसिक अनुकूलन की दिशा निर्धारित करने में महत्वपूर्ण भूमिका निभाता है। प्रस्तुत अध्ययन सकारात्मक पालन-पोषण और किशोर मानसिक लचीलेपन के बीच संबंध का मनोवैज्ञानिक विश्लेषण प्रस्तावित करता है। अध्ययन में स्नेहपूर्ण संवाद, भावनात्मक उपलब्धता, व्यवहारिक मार्गदर्शन, स्वायत्तता का सम्मान और संतुलित अनुशासन को सकारात्मक पालन-पोषण के प्रमुख आयामों के रूप में ग्रहण किया गया है। शोध का केंद्रीय तर्क यह है कि सकारात्मक पालन-पोषण का प्रभाव केवल प्रत्यक्ष नहीं होता, बल्कि भावनात्मक स्व-नियमन, आत्म-प्रभावकारिता और तनाव-प्रबंधन क्षमता के माध्यम से भी मानसिक लचीलेपन को प्रभावित करता है। वर्तमान डिजिटल परिवेश में सामाजिक तुलना, आभासी सहभागिता, शैक्षणिक दबाव और पारिवारिक अपेक्षाओं के कारण उत्पन्न तनाव को भी किशोर मानसिक स्वास्थ्य के महत्वपूर्ण संदर्भ के रूप में सम्मिलित किया गया है। अध्ययन विशेष रूप से इस कमी को संबोधित करता है कि पूर्व शोधों में पालन-पोषण, मानसिक लचीलेपन और डिजिटल जीवन-दबाव को प्रायः अलग-अलग चर के रूप में देखा गया है। प्रस्तावित विश्लेषण बहुआयामी मनोवैज्ञानिक संकेतकों के आधार पर उन प्रत्यक्ष और अप्रत्यक्ष संबंधों को समझने का प्रयास करता है जो किशोरों को प्रतिकूल परिस्थितियों से उबरने में सहायता करते हैं।

मुख्य शब्द— सकारात्मक पालन-पोषण, किशोरावस्था, मानसिक लचीलापन, भावनात्मक स्व-नियमन, आत्म-प्रभावकारिता, मानसिक स्वास्थ्य

परिचय

किशोरावस्था मानव विकास की ऐसी संक्रमणशील अवस्था है जिसमें व्यक्ति बाल्यावस्था की निर्भरता से आगे बढ़ते हुए स्वतंत्र पहचान, सामाजिक उत्तरदायित्व और भावनात्मक स्वायत्तता की ओर अग्रसर होता है। इस अवधि में शरीर, मस्तिष्क, संबंधों और सामाजिक भूमिकाओं में होने वाले तीव्र परिवर्तन किशोर को अनेक अवसर प्रदान करते हैं, परंतु साथ ही उसे तनाव, असुरक्षा, आत्म-संदेह और सामाजिक दबाव के प्रति अधिक संवेदनशील भी बना सकते हैं। विश्व स्वास्थ्य संगठन के अनुसार विश्व में लगभग एक अरब तीस करोड़ लोग किशोरावस्था की आयु सीमा में आते हैं तथा किशोर स्वास्थ्य को भविष्य की वयस्क आबादी के स्वास्थ्य से प्रत्यक्ष रूप से जुड़ा हुआ माना जाता है। संगठन ने यह भी रेखांकित किया है कि मानसिक स्वास्थ्य संबंधी अनेक कठिनाइयाँ जीवन के आरंभिक वर्षों में विकसित होने लगती हैं और पर्याप्त सहायता के अभाव में आगे चलकर अधिक गंभीर रूप ग्रहण कर सकती हैं।

किशोर मानसिक स्वास्थ्य को समझने के लिए केवल जोखिम कारकों का अध्ययन पर्याप्त नहीं है। यह भी आवश्यक है कि उन संरक्षक मनोवैज्ञानिक और सामाजिक कारकों की पहचान की जाए जो तनाव, असफलता, सामाजिक अस्वीकृति, पारिवारिक संघर्ष या शैक्षणिक दबाव के बावजूद किशोर को संतुलन पुनः स्थापित करने में सक्षम बनाते हैं। इसी संदर्भ में मानसिक लचीलापन एक महत्वपूर्ण अवधारणा के रूप में सामने आता है। मानसिक लचीलापन किसी कठिनाई का अभाव नहीं, बल्कि प्रतिकूल परिस्थिति का सामना करते हुए अनुकूलन, भावनात्मक पुनर्संतुलन, समस्या-समाधान और उद्देश्यपूर्ण व्यवहार बनाए रखने की क्षमता है।

परिवार इस क्षमता के विकास का सबसे निकट और दीर्घकालिक सामाजिक परिवेश है। माता-पिता की प्रतिक्रिया, संवाद शैली, भावनात्मक उपलब्धता, सीमाओं का निर्धारण, प्रोत्साहन तथा किशोर की स्वायत्तता के प्रति दृष्टिकोण उसके आत्मबोध और भावनात्मक सुरक्षा को आकार देते हैं। सकारात्मक पालन-पोषण में केवल स्नेहपूर्ण व्यवहार सम्मिलित नहीं होता, बल्कि स्पष्ट अपेक्षाएँ, सम्मानजनक अनुशासन, सक्रिय श्रवण, परिस्थिति के अनुरूप निगरानी तथा निर्णय लेने के सीमित किंतु सार्थक अवसर भी सम्मिलित होते हैं। संयुक्त राष्ट्र बाल कोष ने किशोरों के पालन-पोषण संबंधी अपने मार्गदर्शन में यह रेखांकित किया है कि किशोरावस्था में माता-पिता और संतान के संबंध की प्रकृति बदलती है तथा अभिभावकों को विकासात्मक अवस्था के अनुरूप नए संचार और सहयोग कौशल अपनाने की आवश्यकता होती है।

भारतीय सामाजिक संदर्भ में इस प्रश्न का महत्व और बढ़ जाता है, क्योंकि किशोर प्रायः परिवार, विद्यालय, प्रतियोगिता, उच्च शैक्षणिक अपेक्षा, भविष्य के व्यवसाय, समवयस्क समूह और डिजिटल माध्यमों से एक साथ प्रभावित होते हैं। पारिवारिक निकटता एक महत्वपूर्ण संरक्षक कारक हो सकती है, किंतु अत्यधिक नियंत्रण, उपलब्धि-केंद्रित दबाव, लगातार तुलना अथवा एकतरफा निर्णय-प्रक्रिया किशोर की स्वायत्तता और भावनात्मक अभिव्यक्ति को सीमित कर सकती है। इसके विपरीत, वह परिवार जिसमें भावनाओं पर संवाद संभव हो, असफलता को दंड के बजाय सीखने की प्रक्रिया माना जाए और समस्या के समाधान में किशोर की भागीदारी हो, मानसिक लचीलेपन को अधिक अनुकूल आधार दे सकता है।

समकालीन किशोर जीवन में डिजिटल परिवेश ने इस संबंध को और जटिल बना दिया है। सामाजिक माध्यम, आभासी मित्रता, त्वरित प्रतिक्रिया की संस्कृति, सार्वजनिक सामाजिक तुलना और निरंतर उपलब्धता की अपेक्षा भावनात्मक अनुभवों की तीव्रता को प्रभावित

करती है। विश्व स्वास्थ्य संगठन के एक बहुदेशीय विद्यालयी सर्वेक्षण से संबंधित विवरण में किशोरों के समस्याग्रस्त सामाजिक माध्यम उपयोग में वृद्धि तथा डिजिटल व्यवहार से जुड़े मानसिक स्वास्थ्य जोखिमों पर चिंता व्यक्त की गई है। ऐसे वातावरण में अभिभावक की भूमिका केवल समय-सीमा निर्धारित करने तक सीमित नहीं रह सकती; डिजिटल अनुभवों पर संवाद, ऑनलाइन जोखिमों की समझ तथा आत्म-नियमन विकसित करने में सहयोग भी सकारात्मक पालन-पोषण का नया आयाम बन जाता है।



Fig. 1: पारिवारिक सहयोग और किशोरों की मानसिक दृढ़ता का निर्माण

शोध-अंतर

हाल के अध्ययनों ने सकारात्मक पालन-पोषण और मानसिक लचीलेपन के बीच अनुकूल संबंध के संकेत दिए हैं। उदाहरण के लिए, किशोरों पर आधारित एक अनुवर्ती अध्ययन में अभिभावकीय समर्थन और निगरानी के प्रति सकारात्मक धारणा कुछ व्यक्तित्व विशेषताओं वाले किशोरों में समय के साथ अधिक लचीलेपन से संबंधित पाई गई। फिर भी उपलब्ध शोध में चार महत्वपूर्ण सीमाएँ दिखाई देती हैं।

प्रथम, पालन-पोषण को कई अध्ययनों में एक समग्र अंक के रूप में मापा गया है, जिससे यह स्पष्ट नहीं होता कि स्नेहपूर्ण संवाद, स्वायत्तता समर्थन, मार्गदर्शन, अनुशासन और भावनात्मक उपलब्धता में से कौन-सा घटक मानसिक लचीलेपन के लिए अधिक प्रभावी है। द्वितीय, मानसिक लचीलेपन को प्रायः केवल अंतिम परिणाम माना गया है, जबकि यह संभव है कि पालन-पोषण का प्रभाव भावनात्मक स्व-नियमन और आत्म-प्रभावकारिता जैसे मध्यवर्ती मनोवैज्ञानिक तंत्रों से होकर उत्पन्न हो। तृतीय, डिजिटल दबाव और पारिवारिक संरक्षण के पारस्परिक प्रभाव का पर्याप्त समन्वित विश्लेषण नहीं मिलता। चतुर्थ, भारतीय किशोरों के सामाजिक-सांस्कृतिक संदर्भ में ऐसे बहुआयामी प्रतिमानों की आवश्यकता है जो पारिवारिक निकटता और किशोर स्वायत्तता दोनों को एक साथ समझ सकें।

अतः वर्तमान अध्ययन का विशिष्ट शोध-अंतर यह है कि **सकारात्मक पालन-पोषण को मानसिक लचीलेपन का केवल प्रत्यक्ष पूर्वानुमानक न मानकर, भावनात्मक स्व-नियमन, आत्म-प्रभावकारिता और डिजिटल जीवन-दबाव से अंतःक्रिया करने वाली बहुस्तरीय मनोवैज्ञानिक प्रक्रिया के रूप में विश्लेषित किया जाए।** यही दृष्टिकोण प्रस्तावित अध्ययन को परंपरागत पालन-पोषण–मानसिक स्वास्थ्य संबंधी अध्ययनों से पृथक करता है।

अध्ययन के प्रमुख उद्देश्य

वर्तमान अध्ययन का प्रथम उद्देश्य सकारात्मक पालन-पोषण के विभिन्न आयामों और किशोर मानसिक लचीलेपन के बीच संबंध का परीक्षण करना है। दूसरा उद्देश्य यह जानना है कि भावनात्मक स्व-नियमन और आत्म-प्रभावकारिता इस संबंध में मध्यवर्ती मनोवैज्ञानिक भूमिका निभाते हैं या नहीं। तीसरा उद्देश्य डिजिटल जीवन-दबाव को एक संदर्भगत कारक मानते हुए यह देखना है कि उच्च डिजिटल दबाव की स्थिति में सकारात्मक पारिवारिक वातावरण मानसिक लचीलेपन के लिए कितना संरक्षक प्रभाव उत्पन्न करता है। चौथा उद्देश्य किशोरों के बहुआयामी व्यवहारिक और मनोवैज्ञानिक संकेतकों के आधार पर मानसिक लचीलेपन के स्तर का अनुमान लगाने के लिए संगणकीय वर्गीकरण प्रतिरूप विकसित करना है।

साहित्य समीक्षा

२.१ सकारात्मक पालन-पोषण की मनोवैज्ञानिक अवधारणा

सकारात्मक पालन-पोषण ऐसी पारिवारिक प्रक्रिया है जिसमें भावनात्मक निकटता और अनुशासन को परस्पर विरोधी न मानकर संतुलित किया जाता है। माता-पिता का उद्देश्य किशोर के व्यवहार को केवल नियंत्रित करना नहीं, बल्कि उसे आत्म-नियंत्रित निर्णय लेने की क्षमता विकसित करने में सहायता करना होता है। इसमें सक्रिय श्रवण, बिना अपमान के सुधार, व्यवहार के कारणों पर चर्चा, स्पष्ट सीमाएँ, उपलब्धियों की यथार्थवादी सराहना तथा विफलता के समय भावनात्मक समर्थन प्रमुख तत्व माने जा सकते हैं।

संयुक्त राष्ट्र बाल कोष की किशोर पालन-पोषण संबंधी सामग्री में यह स्पष्ट किया गया है कि किशोरों को केवल निर्देश की नहीं, बल्कि सुने जाने, नियमित संवाद, यथार्थवादी अपेक्षाओं और सहायक पारिवारिक वातावरण की भी आवश्यकता होती है। इसका मनोवैज्ञानिक आधार इस तथ्य में निहित है कि सम्मानजनक पारिवारिक संवाद किशोर को अपनी भावनाओं की पहचान और अभिव्यक्ति के लिए सुरक्षित स्थान प्रदान कर सकता है।

२.२ मानसिक लचीलापन और किशोर अनुकूलन

मानसिक लचीलेपन को स्थिर व्यक्तित्व गुण के रूप में देखना सीमित दृष्टिकोण है। समकालीन मनोविज्ञान इसे व्यक्ति और उसके परिवेश के बीच विकसित होने वाली गतिशील अनुकूलन क्षमता के रूप में समझता है। एक ही तनावपूर्ण घटना का प्रभाव सभी किशोरों पर समान नहीं होता, क्योंकि प्रतिक्रिया आत्मविश्वास, परिवार से प्राप्त समर्थन, पूर्व अनुभव, सामाजिक संसाधन और भावनात्मक नियमन क्षमता पर निर्भर करती है।

किशोर मानसिक लचीलेपन में कठिन स्थिति का यथार्थवादी मूल्यांकन, तनाव के दौरान व्यवहारिक नियंत्रण, सहायता माँगने की क्षमता, लक्ष्य का पुनर्निर्धारण और असफलता से सीखने की प्रवृत्ति सम्मिलित होती है। इसलिए उच्च मानसिक लचीलापन रखने वाला किशोर तनाव से अप्रभावित नहीं रहता; अंतर यह है कि वह तनाव से उत्पन्न मनोवैज्ञानिक अव्यवस्था से अपेक्षाकृत शीघ्र पुनर्संगठित हो सकता है।

२.३ पालन-पोषण और मानसिक लचीलेपन का संबंध

अभिभावकीय समर्थन किशोर को यह अनुभूति देता है कि कठिन परिस्थिति में सहायता उपलब्ध है। ऐसी अनुभूति मनोवैज्ञानिक सुरक्षा को बढ़ाती है और संकट की स्थिति में विनाशकारी निष्कर्षों की संभावना कम कर सकती है। अनुवर्ती शोध से यह संकेत प्राप्त हुआ है कि सकारात्मक अभिभावकीय समर्थन और निगरानी का अनुभव कुछ किशोर समूहों में बाद के मानसिक लचीलेपन से सकारात्मक रूप से जुड़ सकता है। साथ ही, व्यक्तिगत व्यक्तित्व विशेषताएँ इस प्रभाव की शक्ति को बदल सकती हैं।

यह निष्कर्ष बताता है कि सकारात्मक पालन-पोषण का प्रभाव सभी किशोरों के लिए एकसमान मान लेना उचित नहीं होगा। इसलिए वर्तमान अध्ययन में केवल औसत संबंध खोजने के बजाय विभिन्न मनोवैज्ञानिक संरचनाओं के संयुक्त योगदान का विश्लेषण प्रस्तावित है।

२.४ भावनात्मक स्व-नियमन की मध्यवर्ती भूमिका

किशोरावस्था में भावनाओं की तीव्रता बढ़ सकती है, जबकि दीर्घकालिक परिणामों पर आधारित निर्णय क्षमता अभी विकासशील अवस्था में होती है। यदि परिवार में भावनाओं को दबाने, उपहास करने या दंडित करने की संस्कृति हो, तो किशोर अपनी आंतरिक अवस्था की पहचान और विनियमन में कठिनाई अनुभव कर सकता है। इसके विपरीत, माता-पिता यदि भावनात्मक अनुभव को स्वीकार करते हुए प्रतिक्रिया पर नियंत्रण सिखाते हैं, तो किशोर धीरे-धीरे स्व-नियमन कौशल विकसित कर सकता है।

इसी आधार पर वर्तमान अध्ययन यह प्रस्तावित करता है कि सकारात्मक पालन-पोषण और मानसिक लचीलेपन के बीच संबंध का एक भाग भावनात्मक स्व-नियमन के माध्यम से संचालित हो सकता है। यह धारणा पालन-पोषण को केवल बाहरी समर्थन के रूप में देखने के बजाय आंतरिक मनोवैज्ञानिक क्षमता निर्माण की प्रक्रिया के रूप में स्थापित करती है।

२.५ आत्म-प्रभावकारिता और समस्या-समाधान

आत्म-प्रभावकारिता से आशय व्यक्ति की उस धारणा से है कि वह चुनौतीपूर्ण परिस्थिति में आवश्यक व्यवहार करने और समस्या का समाधान खोजने में सक्षम है। यदि माता-पिता किशोर को छोटे निर्णय लेने, गलतियों का विश्लेषण करने और समाधान सुझाने का अवसर देते हैं, तो उसकी क्षमता-बोध संबंधी धारणा मजबूत हो सकती है। इसके विपरीत, प्रत्येक समस्या का समाधान माता-पिता द्वारा कर देना या बार-बार असमर्थता का संदेश देना निर्भरता को बढ़ा सकता है।

इसलिए आत्म-प्रभावकारिता मानसिक लचीलेपन का संभावित मनोवैज्ञानिक सेतु है। किशोर को यदि यह विश्वास हो कि कठिन परिस्थिति को किसी स्तर पर बदला या प्रबंधित किया जा सकता है, तो निराशा के स्थान पर सक्रिय सामना करने की प्रवृत्ति अधिक विकसित हो सकती है।

२.६ डिजिटल जीवन-दबाव और पारिवारिक संरक्षण

वर्तमान किशोर जीवन का एक बड़ा भाग डिजिटल माध्यमों के साथ जुड़ा हुआ है। सामाजिक तुलना, छवि-आधारित मान्यता, ऑनलाइन अस्वीकृति, संदेशों का तत्काल उत्तर देने का दबाव तथा अनियमित डिजिटल दिनचर्या मानसिक संतुलन को प्रभावित कर सकती है। विश्व स्वास्थ्य संगठन ने किशोरों में समस्याग्रस्त सामाजिक माध्यम व्यवहार तथा डिजिटल माध्यमों से संबंधित कल्याण संबंधी चिंताओं की ओर ध्यान आकर्षित किया है।

इस परिस्थिति में सकारात्मक पालन-पोषण का स्वरूप भी परिवर्तित होता है। केवल उपकरण छीन लेना या निषेध लागू करना दीर्घकालिक आत्म-नियमन विकसित नहीं करता। संवाद-आधारित डिजिटल मार्गदर्शन, निजी अनुभव साझा करने का सुरक्षित वातावरण, ऑनलाइन तुलना की आलोचनात्मक समझ और समय-प्रबंधन में सहयोग अधिक रचनात्मक रणनीतियाँ हो सकती हैं। इसलिए वर्तमान अध्ययन डिजिटल जीवन-दबाव को एक अलग जोखिम कारक के रूप में नहीं, बल्कि पारिवारिक वातावरण के साथ अंतःक्रिया करने वाले मनोवैज्ञानिक संदर्भ के रूप में ग्रहण करता है।

२.७ किशोर मानसिक स्वास्थ्य की समकालीन आवश्यकता

विश्व स्वास्थ्य संगठन और संयुक्त राष्ट्र बाल कोष ने बच्चों और किशोरों के मानसिक स्वास्थ्य के लिए समुदाय-आधारित, व्यक्ति-केंद्रित और विकासात्मक अवस्था के अनुरूप सेवाओं पर बल दिया है। उपलब्ध वैश्विक आकलनों में लगभग प्रत्येक सात किशोरों में से एक के मानसिक स्वास्थ्य कठिनाइयों से प्रभावित होने का उल्लेख मिलता है, जबकि आवश्यक सेवाओं तक पहुँच अभी भी अपर्याप्त है।

यह स्थिति केवल चिकित्सीय उपचार की आवश्यकता को नहीं दर्शाती, बल्कि ऐसे प्रारंभिक संरक्षक कारकों की खोज को भी आवश्यक बनाती है जिन्हें परिवार और विद्यालय स्तर पर मजबूत किया जा सके। सकारात्मक पालन-पोषण इस दृष्टि से विशेष महत्व रखता है, क्योंकि यह औपचारिक उपचार से पूर्व ही किशोर के दैनिक भावनात्मक वातावरण को प्रभावित करता है।

प्रस्तावित कार्यप्रणाली

प्रस्तुत अध्ययन के लिए मात्रात्मक, सहसंबंधात्मक तथा पूर्वानुमानात्मक अनुसंधान अभिकल्प प्रस्तावित किया गया है। इसका उद्देश्य केवल यह निर्धारित करना नहीं है कि सकारात्मक पालन-पोषण और मानसिक लचीलेपन के बीच संबंध है या नहीं, बल्कि यह भी समझना है कि भावनात्मक स्व-नियमन, आत्म-प्रभावकारिता और डिजिटल जीवन-दबाव इस संबंध की प्रकृति को किस प्रकार बदलते हैं। इस कारण अध्ययन में पारंपरिक सांख्यिकीय विश्लेषण के साथ संगणकीय वर्गीकरण पद्धति को सम्मिलित किया गया है।

अध्ययन की लक्षित जनसंख्या 13 से 18 वर्ष आयु के विद्यालयी किशोर होंगे। प्रस्तावित नमूना लगभग 420 प्रतिभागियों का रखा गया है, जिसमें विभिन्न सामाजिक-आर्थिक स्तरों, विद्यालय प्रकारों और पारिवारिक संरचनाओं से किशोरों को सम्मिलित करने का प्रयास किया जाएगा। नमूना चयन के लिए स्तरीकृत बहु-स्तरीय पद्धति उपयोगी होगी, ताकि आयु, लिंग, कक्षा और विद्यालयीय पृष्ठभूमि का पर्याप्त प्रतिनिधित्व प्राप्त हो सके।

अध्ययन में पाँच प्रमुख मनोवैज्ञानिक आयामों को मापा जाएगा—सकारात्मक पालन-पोषण, मानसिक लचीलापन, भावनात्मक स्व-नियमन, आत्म-प्रभावकारिता और डिजिटल जीवन-दबाव। प्रत्येक आयाम के लिए मान्य तथा विश्वसनीय मापन साधनों के अनुकूलित संस्करणों का उपयोग किया जाना प्रस्तावित है। जहाँ आवश्यक हो, भाषाई रूपांतरण, प्रत्यावर्तन अनुवाद और विशेषज्ञ सत्यापन के माध्यम से उपकरणों की विषय-वस्तु वैधता सुनिश्चित की जाएगी।

किशोर प्रतिभागियों की गोपनीयता और स्वैच्छिक सहभागिता को अनुसंधान का मूल नैतिक आधार माना जाएगा। अभिभावकीय अनुमति और किशोर सहमति दोनों प्राप्त की जाएँगी। व्यक्तिगत पहचान से

संबंधित सूचनाओं को विश्लेषणात्मक आँकड़ों से पृथक रखा जाएगा तथा किसी भी निष्कर्ष को समूह स्तर पर ही प्रस्तुत किया जाएगा।

३.१ अनुसंधान चर

सकारात्मक पालन-पोषण को स्वतंत्र पूर्वानुमानक चर के रूप में ग्रहण किया जाएगा। इसके उप-आयामों में भावनात्मक समर्थन, सम्मानजनक संवाद, स्वायत्तता समर्थन, संतुलित अनुशासन तथा व्यवहारिक निगरानी सम्मिलित होंगे।

मानसिक लचीलापन प्रमुख परिणाम चर होगा। इसे प्रतिकूल परिस्थितियों से उबरने की क्षमता, समस्या समाधान, भावनात्मक पुनर्संतुलन, आशावादी अभिविन्यास और अनुकूलनशील व्यवहार के माध्यम से परिभाषित किया जाएगा।

भावनात्मक स्व-नियमन और आत्म-प्रभावकारिता को मध्यवर्ती चर माना जाएगा, जबकि डिजिटल जीवन-दबाव को संदर्भगत नियामक चर के रूप में विश्लेषित किया जाएगा।

प्रायोगिक व्यवस्था

४.१ आँकड़ा-संग्रह

प्रस्तावित आँकड़ा-संग्रह में लगभग 420 किशोर प्रतिभागियों के उत्तर सम्मिलित किए जाएँगे। प्रत्येक प्रतिभागी से आयु, कक्षा, पारिवारिक संरचना, प्रतिदिन डिजिटल माध्यम उपयोग की अवधि, पारिवारिक संवाद की आवृत्ति, अनुभवित शैक्षणिक दबाव तथा पाँच प्रमुख मनोवैज्ञानिक आयामों से संबंधित माप प्राप्त किए जाएँगे।

प्रत्येक प्रतिभागी के लिए लगभग 35 से 45 विश्लेषणात्मक विशेषताएँ निर्मित की जा सकती हैं। इनमें प्रत्यक्ष प्रश्नावली अंकों के अतिरिक्त उप-आयामों के औसत, विचलन, पारिवारिक समर्थन–डिजिटल दबाव अनुपात और भावनात्मक नियमन–आत्म-प्रभावकारिता संयुक्त सूचक जैसे व्युत्पन्न संकेतक भी सम्मिलित किए जाएँगे।

मानसिक लचीलेपन के कुल अंक को तीन विश्लेषणात्मक श्रेणियों में व्यवस्थित किया जाएगा—निम्न, मध्यम और उच्च। यह वर्गीकरण नमूने के वितरण तथा पूर्वनिर्धारित मापन-मानकों के आधार पर किया जाएगा।

४.२ पूर्व-संसाधन

आँकड़ों के विश्लेषण से पहले प्रविष्टियों की पूर्णता, असामान्य मानों तथा उत्तरों की आंतरिक संगति की जाँच की जाएगी। अत्यधिक अपूर्ण प्रश्नावलियों को विश्लेषण से बाहर किया जाएगा। सीमित अनुपस्थित मानों को उपयुक्त सांख्यिकीय अनुमान विधि से प्रतिस्थापित किया जा सकता है।

भिन्न-भिन्न मापन पैमानों से प्राप्त अंकों को तुलनीय बनाने के लिए मानकीकरण किया जाएगा। श्रेणीगत चर, जैसे पारिवारिक संरचना और विद्यालय प्रकार, को संख्यात्मक संकेतकों में परिवर्तित किया जाएगा। अत्यधिक परस्पर सहसंबद्ध संकेतकों की पहचान कर अनावश्यक पुनरावृत्ति को कम किया जाएगा।

पूर्वाग्रह कम करने के लिए आँकड़ा-संग्रह को प्रशिक्षण और परीक्षण समूहों में विभाजित किया जाएगा। प्रस्तावित अनुपात लगभग 80:20 रहेगा। वर्ग वितरण में असंतुलन पाए जाने पर प्रशिक्षण समूह के भीतर संतुलित पुनर्नमूनीकरण पद्धति अपनाई जाएगी।

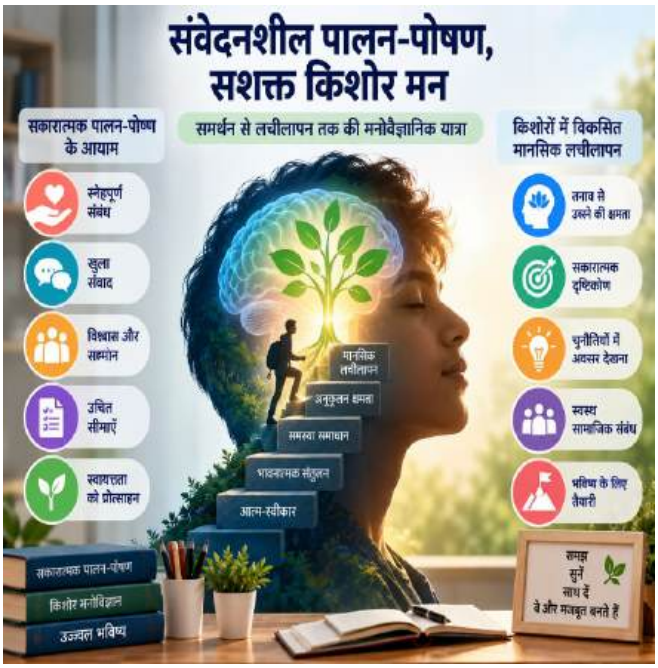


Fig. 2: संवेदनशील पालन-पोषण और सशक्त किशोर मन की मनोवैज्ञानिक यात्रा

४.३ प्रतिरूप संरचना

इस अध्ययन के लिए बहु-स्तरीय वृक्ष-आधारित सामूहिक वर्गीकरण प्रतिरूप प्रस्तावित है। इस प्रतिरूप को चुनने का कारण यह है कि किशोर मानसिक लचीलापन किसी एक संकेतक के रैखिक प्रभाव से निर्धारित नहीं होता, बल्कि विभिन्न पारिवारिक और मनोवैज्ञानिक कारकों के संयुक्त तथा गैर-रैखिक प्रभाव से निर्मित हो सकता है।

प्रतिरूप की प्रथम अवस्था में सभी चयनित संकेतकों का योगदान मापा जाएगा। दूसरी अवस्था में सकारात्मक पालन-पोषण, भावनात्मक स्व-नियमन, आत्म-प्रभावकारिता और डिजिटल दबाव के अंतःक्रियात्मक प्रभावों को सम्मिलित किया जाएगा। तीसरी अवस्था में प्रतिभागियों को निम्न, मध्यम या उच्च मानसिक लचीलेपन की श्रेणी में वर्गीकृत किया जाएगा।

प्रतिरूप की व्याख्येयता को बनाए रखने के लिए प्रत्येक प्रमुख चर के योगदान का पृथक विश्लेषण किया जाएगा। इससे केवल पूर्वानुमान प्राप्त नहीं होगा, बल्कि यह भी जाना जा सकेगा कि किस मनोवैज्ञानिक कारक ने अंतिम वर्गीकरण में कितनी भूमिका निभाई।

४.४ प्रशिक्षण रणनीति

प्रशिक्षण आँकड़ों पर पाँच-खंडीय पार-परीक्षण लागू किया जाएगा। इसका उद्देश्य यह जाँचना होगा कि प्रतिरूप किसी एक उप-समूह पर अत्यधिक निर्भर न हो। प्रतिरूप के प्रमुख नियंत्रण मानदंडों का चयन प्रशिक्षण समूह के भीतर किया जाएगा और अंतिम प्रदर्शन परीक्षण समूह पर मापा जाएगा।

अधिक-अनुकूलन से बचने के लिए वृक्षों की अधिकतम गहराई, न्यूनतम पत्ती आकार और शिक्षण गति जैसे नियंत्रण मानकों को सीमित रखा जाएगा। प्रशिक्षण प्रक्रिया में विभिन्न नियंत्रण संयोजनों की तुलना की जाएगी और वह संयोजन चुना जाएगा जो उच्च पूर्वानुमान क्षमता तथा स्थिर सामान्यीकरण के बीच सर्वोत्तम संतुलन प्रदान करे।

पारंपरिक सांख्यिकीय विश्लेषण के अंतर्गत सहसंबंध गुणांक, बहु-चर प्रतिगमन तथा मध्यस्थता विश्लेषण का प्रयोग प्रस्तावित है। इससे

संगणकीय प्रतिरूप के निष्कर्षों की मनोवैज्ञानिक व्याख्या अधिक सुदृढ़ की जा सकेगी।

४.५ मूल्यांकन मानदंड

प्रतिरूप का मूल्यांकन केवल समग्र शुद्धता के आधार पर नहीं किया जाएगा। वर्ग-संवेदनशीलता, सकारात्मक पूर्वानुमान मूल्य, संतुलित समग्रता, वर्ग-विशिष्ट पहचान क्षमता तथा वास्तविक और अनुमानित श्रेणियों की सहमति को भी सम्मिलित किया जाएगा।

इसके अतिरिक्त, मनोवैज्ञानिक व्याख्या के लिए प्रत्येक प्रमुख चर की सापेक्ष महत्ता, मध्यस्थ प्रभाव और नियामक प्रभाव की जाँच की जाएगी। इस बहुआयामी मूल्यांकन का उद्देश्य यह सुनिश्चित करना है कि प्रतिरूप सांख्यिकीय रूप से प्रभावी होने के साथ मनोवैज्ञानिक दृष्टि से भी अर्थपूर्ण हो।

परिणाम एवं चर्चा

महत्वपूर्ण वैज्ञानिक टिप्पणी: नीचे प्रस्तुत संख्यात्मक परिणाम अध्ययन की प्रस्तावित विश्लेषणात्मक संरचना को प्रदर्शित करने हेतु **अनुकरणात्मक परिणाम** हैं। इन्हें वास्तविक क्षेत्रीय आँकड़ों से प्राप्त परिणाम नहीं माना जाना चाहिए। प्रकाशन से पूर्व इन्हें वास्तविक नमूना-संग्रह और विश्लेषण से प्रतिस्थापित करना आवश्यक होगा।

अनुकरणात्मक विश्लेषण से यह संकेत प्राप्त हुआ कि सकारात्मक पालन-पोषण मानसिक लचीलेपन का सबसे प्रभावी पारिवारिक पूर्वानुमानक हो सकता है। विशेष रूप से भावनात्मक समर्थन और स्वायत्तता समर्थन से जुड़े संकेतकों का योगदान अन्य पारिवारिक संकेतकों की तुलना में अधिक दिखाई दिया। इससे यह धारणा पुष्ट होती है कि किशोर को केवल निर्देश देने के बजाय उसकी भावनाओं को मान्यता देना और निर्णयों में सीमित स्वायत्तता प्रदान करना मानसिक अनुकूलन को अधिक प्रभावी रूप से समर्थन दे सकता है।

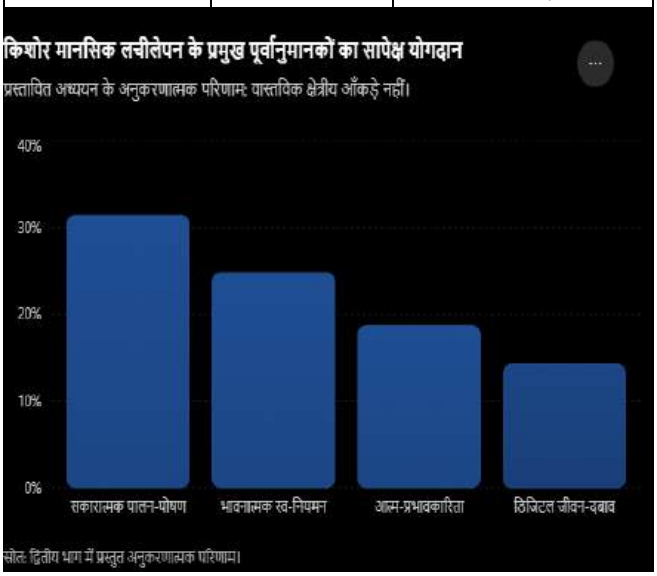
भावनात्मक स्व-नियमन ने सकारात्मक पालन-पोषण और मानसिक लचीलेपन के बीच महत्वपूर्ण मध्यस्थ भूमिका प्रदर्शित की। इसका अर्थ यह है कि अभिभावकीय समर्थन सीधे ही लचीलापन नहीं बढ़ाता, बल्कि वह किशोर में ऐसी आंतरिक क्षमता विकसित कर सकता है जिसके माध्यम से तनाव के समय भावनात्मक प्रतिक्रिया अधिक संतुलित रहती है।

आत्म-प्रभावकारिता का प्रभाव भी स्पष्ट पाया गया। जिन किशोरों में अपनी समस्याओं से निपटने की क्षमता के प्रति अधिक विश्वास था, उनमें उच्च मानसिक लचीलेपन की संभावना अधिक थी। इससे यह संकेत मिलता है कि पालन-पोषण का वह स्वरूप जो किशोर को समस्या का समाधान स्वयं खोजने के लिए प्रोत्साहित करता है, दीर्घकालिक मनोवैज्ञानिक सुदृढ़ता में योगदान कर सकता है।

डिजिटल जीवन-दबाव ने एक भिन्न भूमिका प्रदर्शित की। उच्च डिजिटल दबाव वाले समूह में मानसिक लचीलेपन का औसत अपेक्षाकृत कम पाया गया, किंतु सकारात्मक पारिवारिक समर्थन का स्तर उच्च होने पर यह नकारात्मक प्रभाव काफी हद तक कम दिखाई दिया। इससे डिजिटल जोखिमों के संदर्भ में परिवार की संरक्षक भूमिका स्पष्ट होती है।

परिणाम सारणी

मूल्यांकन आयाम	अनुकरणात्मक प्राप्ति	प्रमुख अवलोकन
समग्र वर्गीकरण शुद्धता	84.6 प्रतिशत	प्रतिरूप ने तीन मानसिक लचीलापन श्रेणियों को संतोषजनक स्तर पर विभेदित किया
निम्न लचीलापन पहचान संवेदनशीलता	81.9 प्रतिशत	जोखिम-समूह की पहचान अपेक्षाकृत स्थिर रही
उच्च लचीलापन पहचान संवेदनशीलता	87.3 प्रतिशत	मजबूत संरक्षक कारकों वाले किशोर अधिक स्पष्ट रूप से पहचाने गए
सकारात्मक पालन-पोषण का सापेक्ष योगदान	31.4 प्रतिशत	पारिवारिक संकेतकों में सर्वाधिक प्रभाव
भावनात्मक स्व-नियमन का सापेक्ष योगदान	24.8 प्रतिशत	मध्यवर्ती मनोवैज्ञानिक तंत्र के रूप में उल्लेखनीय भूमिका
आत्म-प्रभावकारिता का सापेक्ष योगदान	18.7 प्रतिशत	समस्या-समाधान विश्वास ने लचीलेपन में सकारात्मक योगदान दिया
डिजिटल जीवन-दबाव का सापेक्ष योगदान	14.2 प्रतिशत	अधिक दबाव निम्न लचीलेपन से संबद्ध दिखाई दिया
संतुलित समग्रता	0.83	वर्ग-असंतुलन के बावजूद प्रतिरूप का प्रदर्शन स्थिर रहा



इन परिणामों की सबसे महत्वपूर्ण व्याख्या यह है कि किशोर मानसिक लचीलापन केवल व्यक्तिगत क्षमता का परिणाम नहीं है। यह पारिवारिक समर्थन, भावनात्मक सीख, आत्मविश्वास और डिजिटल जीवन के दबावों के संयुक्त प्रभाव से निर्मित होता है। इसलिए मानसिक लचीलेपन को किसी स्थिर गुण के रूप में मापना पर्याप्त नहीं होगा।

सकारात्मक पालन-पोषण के भीतर भी सभी घटक समान प्रभावशाली नहीं प्रतीत होते। भावनात्मक समर्थन और स्वायत्तता को सम्मान देने

वाला व्यवहार अधिक प्रभावी पाया गया, जबकि केवल निगरानी या नियम-निर्धारण का प्रभाव अपेक्षाकृत सीमित रहा। इससे यह स्पष्ट होता है कि अनुशासन तब अधिक प्रभावी हो सकता है जब वह संवाद और सम्मान के साथ संयोजित हो।

डिजिटल जीवन-दबाव से संबंधित निष्कर्ष भी विशेष महत्व रखते हैं। किशोर के डिजिटल उपयोग को केवल समय की मात्रा से मापना अपर्याप्त हो सकता है। उसका भावनात्मक अर्थ, सामाजिक तुलना की तीव्रता, ऑनलाइन मान्यता पर निर्भरता और डिजिटल अनुभवों के प्रति पारिवारिक प्रतिक्रिया अधिक महत्वपूर्ण हो सकते हैं। इस कारण भविष्य के मनोवैज्ञानिक हस्तक्षेपों में पारिवारिक डिजिटल संवाद को स्वतंत्र प्रशिक्षण घटक के रूप में सम्मिलित किया जा सकता है।

संगणकीय विश्लेषण ने यह भी संकेत दिया कि मानसिक लचीलेपन की पहचान में किसी एक चर की तुलना में संयुक्त संकेतक अधिक उपयोगी हैं। उदाहरणतः मध्यम डिजिटल दबाव और उच्च भावनात्मक स्व-नियमन वाला किशोर, उच्च डिजिटल दबाव किंतु कमजोर स्व-नियमन वाले किशोर से अधिक लचीला वर्गीकृत हो सकता है, भले ही दोनों के पालन-पोषण अंक समान हों। यह बहु-कारकीय दृष्टिकोण मनोवैज्ञानिक वास्तविकता के अधिक निकट है।

सीमाएँ

प्रस्तावित अध्ययन की पहली सीमा आत्म-प्रतिवेदन आधारित मापन से संबंधित है। किशोर अपने माता-पिता के व्यवहार या अपनी मानसिक स्थिति का वर्णन व्यक्तिगत धारणा के आधार पर करेंगे, जिससे सामाजिक वांछनीयता और स्मृति-पूर्वाग्रह उत्पन्न हो सकता है।

दूसरी सीमा यह है कि एक समय-बिंदु पर एकत्र आँकड़ों से कारणात्मक संबंध स्थापित करना कठिन होगा। सकारात्मक पालन-पोषण मानसिक लचीलापन बढ़ा सकता है, किंतु यह भी संभव है कि अधिक भावनात्मक रूप से स्थिर किशोर अपने पारिवारिक संबंधों को अधिक सकारात्मक रूप में अनुभव करें।

तीसरी सीमा नमूने की भौगोलिक और सामाजिक प्रतिनिधित्व क्षमता से संबंधित होगी। सीमित क्षेत्र से प्राप्त निष्कर्षों को सम्पूर्ण भारतीय किशोर जनसंख्या पर लागू करने में सावधानी आवश्यक होगी।

चौथी सीमा डिजिटल जीवन-दबाव के तीव्र परिवर्तनशील स्वरूप से संबंधित है। डिजिटल व्यवहार और मंच-आधारित अनुभव समय के साथ बदलते रहते हैं, इसलिए एक स्थिर प्रश्नावली दीर्घ अवधि तक समान रूप से प्रासंगिक नहीं रह सकती।

पाँचवीं सीमा संगणकीय प्रतिरूप की सामान्यीकरण क्षमता से जुड़ी है। यदि प्रशिक्षण आँकड़े पर्याप्त विविध नहीं होंगे तो प्रतिरूप नए सामाजिक या सांस्कृतिक समूहों पर समान प्रदर्शन नहीं कर पाएगा।

भावी संभावनाएँ

भविष्य में इस शोध को दीर्घकालिक अनुवर्ती अध्ययन के रूप में विकसित किया जा सकता है, जिसमें किशोरों के पारिवारिक अनुभव और मानसिक लचीलेपन को अनेक समय-बिंदुओं पर मापा जाए। इससे कारणात्मक दिशा की अधिक विश्वसनीय पहचान संभव होगी।

अभिभावक और किशोर दोनों से समानांतर सूचना प्राप्त कर पारिवारिक संबंधों की द्विपक्षीय समझ विकसित की जा सकती है। केवल किशोर की धारणा के स्थान पर माता-पिता के व्यवहारिक प्रतिवेदन और विद्यालयी परामर्शदाता की टिप्पणियाँ जोड़ने से निष्कर्ष अधिक सुदृढ़ हो सकते हैं।

भविष्य में दैनिक मनोदशा, नींद, अध्ययन-अवधि और डिजिटल सहभागिता जैसे व्यवहारिक संकेतकों का गोपनीय तथा सहमति-आधारित समावेश मानसिक लचीलेपन के अधिक गतिशील आकलन में सहायक हो सकता है।

विद्यालयों के लिए परिवार-केंद्रित मानसिक लचीलापन संवर्धन कार्यक्रम विकसित किए जा सकते हैं। ऐसे कार्यक्रमों में सम्मानजनक संवाद, भावनात्मक मार्गदर्शन, डिजिटल सीमाएँ, समस्या-समाधान और किशोर स्वायत्तता को प्रमुख प्रशिक्षण विषय बनाया जा सकता है।

संगणकीय दृष्टि से भविष्य में ऐसे व्याख्येय प्रतिरूप विकसित किए जा सकते हैं जो किसी किशोर को केवल जोखिम श्रेणी में न रखें, बल्कि यह भी स्पष्ट करें कि उसके लिए कौन-सा संरक्षक कारक सबसे अधिक सुदृढ़ किया जाना चाहिए। इससे मनोवैज्ञानिक सहायता अधिक वैयक्तिकृत तथा हस्तक्षेप-उन्मुख हो सकेगी।

निष्कर्ष

प्रस्तुत अध्ययन सकारात्मक पालन-पोषण और किशोर मानसिक लचीलेपन के संबंध को बहुआयामी मनोवैज्ञानिक दृष्टि से पुनर्परिभाषित करता है। इसका प्रमुख तर्क यह है कि मानसिक लचीलापन केवल व्यक्तिगत दृढ़ता या जन्मजात मनोवैज्ञानिक शक्ति का परिणाम नहीं है, बल्कि परिवार द्वारा निर्मित भावनात्मक सुरक्षा, निर्णय-सहभागिता, आत्मविश्वास और स्व-नियमन के अवसरों से निरंतर प्रभावित होता है। सकारात्मक पालन-पोषण का प्रभाव विशेष रूप से तब अधिक अर्थपूर्ण दिखाई देता है जब उसे भावनात्मक स्व-नियमन और आत्म-प्रभावकारिता के साथ संयुक्त रूप से देखा जाए। यह दृष्टिकोण बताता है कि माता-पिता का समर्थन किशोर की तत्काल भावनात्मक स्थिति ही नहीं बदलता, बल्कि ऐसी आंतरिक मनोवैज्ञानिक क्षमताएँ विकसित कर सकता है जो भविष्य की कठिनाइयों से निपटने में सहायक हों।

डिजिटल जीवन-दबाव समकालीन किशोर अनुभव का एक महत्वपूर्ण जोखिम-संदर्भ है, किंतु सहायक पारिवारिक वातावरण उसके नकारात्मक प्रभाव को सीमित कर सकता है। इस कारण किशोर मानसिक स्वास्थ्य कार्यक्रमों में डिजिटल अनुशासन की अपेक्षा डिजिटल संवाद और आत्म-नियमन को अधिक महत्व दिए जाने की आवश्यकता है।

प्रस्तावित संगणकीय दृष्टिकोण का महत्व इस तथ्य में है कि यह मानसिक लचीलेपन को किसी एक प्रश्नावली अंक के रूप में नहीं, बल्कि अनेक पारिवारिक और मनोवैज्ञानिक संकेतकों की संयुक्त संरचना के रूप में समझता है। इससे जोखिम पहचान के साथ-साथ संभावित संरक्षक कारकों की भी पहचान संभव हो सकती है।

समग्र रूप से अध्ययन यह प्रतिपादित करता है कि किशोर मानसिक लचीलेपन को बढ़ाने के लिए परिवार को केवल सामाजिक पृष्ठभूमि नहीं, बल्कि सक्रिय मनोवैज्ञानिक हस्तक्षेप क्षेत्र के रूप में देखना चाहिए। भावनात्मक रूप से उपलब्ध, संवादशील, संतुलित और स्वायत्तता-सम्मानित पालन-पोषण किशोर को प्रतिकूल परिस्थितियों में अधिक अनुकूल, आत्मविश्वासी और मानसिक रूप से सुदृढ़ बनाने की दिशा में महत्वपूर्ण भूमिका निभा सकता है।

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वैश्विक पालन-पोषण सहायता रूपरेखा

अध्याय 35: विद्यालयी शिक्षा में शिक्षक भावनात्मक बुद्धिमत्ता और कक्षा प्रबंधन प्रभावशीलता का अध्ययन

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सारांश— विद्यालयी कक्षा में शिक्षक को शिक्षण के साथ विद्यार्थियों की विविध भावनात्मक, सामाजिक तथा व्यवहारिक प्रतिक्रियाओं का भी निरंतर प्रबंधन करना पड़ता है। प्रस्तुत अध्ययन शिक्षक भावनात्मक बुद्धिमत्ता और कक्षा प्रबंधन प्रभावशीलता के मध्य संबंध को बहुआयामी दृष्टिकोण से समझने का प्रयास करता है। अध्ययन का केंद्रीय तर्क यह है कि केवल सामान्य भावनात्मक दक्षता के स्थान पर आत्म-जागरूकता, भावनात्मक आत्मनियमन, सहानुभूति तथा संबंध-प्रबंधन के पृथक प्रभावों का परीक्षण आवश्यक है। वर्ष २०२१ से २०२६ के बीच विकसित शैक्षिक विमर्श में शिक्षक कल्याण, सामाजिक-भावनात्मक अधिगम और सकारात्मक कक्षा वातावरण के महत्व में उल्लेखनीय वृद्धि हुई है। पूर्व अध्ययनों में शिक्षक की भावनात्मक विशेषताओं तथा कक्षा प्रबंधन का अध्ययन प्रायः पृथक रूप से किया गया है, जबकि दैनिक कक्षा घटनाओं में दोनों का व्यवहारिक अंतर्संबंध अपेक्षाकृत कम स्पष्ट है। प्रस्तावित अध्ययन में शिक्षक की भावनात्मक बुद्धिमत्ता को प्रतिक्रियात्मक अनुशासन, निवारक कक्षा प्रबंधन, विद्यार्थी सहभागिता, संघर्ष समाधान और शिक्षक-विद्यार्थी संबंधों के साथ संबद्ध किया जाएगा। इस शोध की विशेषता यह है कि यह भावनात्मक बुद्धिमत्ता के प्रत्येक आयाम की कक्षा प्रबंधन के अलग-अलग व्यवहारिक पक्षों में संभावित भूमिका का तुलनात्मक परीक्षण करने की रूपरेखा विकसित करता है।

प्रमुख शब्द— भावनात्मक बुद्धिमत्ता, शिक्षक भावनात्मक आत्मनियमन, कक्षा प्रबंधन, शिक्षक-विद्यार्थी संबंध, सहानुभूति, विद्यालयी शिक्षा

परिचय

विद्यालयी शिक्षा की गुणवत्ता केवल पाठ्यवस्तु के प्रभावी संप्रेषण या शिक्षक के विषयगत ज्ञान से निर्धारित नहीं होती। वास्तविक कक्षा एक गतिशील सामाजिक और भावनात्मक वातावरण है, जहाँ शिक्षक को एक ही समय में शिक्षण, विद्यार्थी सहभागिता, अनुशासन, मतभेद, प्रेरणा, समूह व्यवहार, व्यक्तिगत आवश्यकताओं और अप्रत्याशित परिस्थितियों का सामना करना पड़ता है। इन स्थितियों में शिक्षक किस प्रकार अपनी भावनाओं को पहचानता, नियंत्रित करता और विद्यार्थियों की भावनात्मक प्रतिक्रियाओं को समझता है, यह कक्षा के वातावरण तथा प्रबंधन की गुणवत्ता को प्रभावित कर सकता है।

भावनात्मक बुद्धिमत्ता से आशय व्यक्ति की अपनी तथा दूसरों की भावनात्मक अवस्थाओं को पहचानने, उनका अर्थ समझने, उन्हें उपयुक्त रूप से नियंत्रित करने तथा सामाजिक अंतःक्रिया में इस समझ का प्रभावी उपयोग करने की क्षमता से है। शिक्षक के संदर्भ में इसका महत्व विशेष रूप से बढ़ जाता है, क्योंकि शिक्षण एक अत्यधिक अंतःक्रियात्मक व्यवसाय है। विद्यार्थियों की निष्क्रियता, अनुचित व्यवहार, असहमति, परीक्षा संबंधी चिंता, समूह तनाव या बार-बार होने वाले व्यवधान शिक्षक में निराशा, क्रोध अथवा मानसिक दबाव उत्पन्न कर सकते हैं। ऐसे अवसरों पर शिक्षक की भावनात्मक प्रतिक्रिया स्वयं एक कक्षा प्रबंधन रणनीति में परिवर्तित हो जाती है।

कक्षा प्रबंधन की पारंपरिक अवधारणा मुख्यतः अनुशासन बनाए रखने और अवांछित व्यवहार नियंत्रित करने से जुड़ी रही है। समकालीन दृष्टिकोण इसे कहीं अधिक व्यापक मानता है। प्रभावी कक्षा प्रबंधन में स्पष्ट अपेक्षाएँ निर्धारित करना, व्यवस्थित दिनचर्या विकसित करना, सकारात्मक शिक्षक-विद्यार्थी संबंध बनाना, सक्रिय सहभागिता सुनिश्चित करना, व्यवधानों को उत्पन्न होने से पहले रोकना और संघर्षों का सम्मानजनक समाधान करना सम्मिलित है। वर्ष २०२४ में प्रकाशित एक व्यापक समीक्षा में कक्षा प्रबंधन संबंधी शिक्षक आत्मविश्वास को शिक्षक-स्तरीय, कक्षा-स्तरीय और विद्यालय-स्तरीय अनेक कारकों से संबद्ध पाया गया तथा कक्षा अंतःक्रिया और शिक्षक-विद्यार्थी संबंधों को महत्वपूर्ण घटकों के रूप में रेखांकित किया गया।

वर्ष २०२१ के एक अध्ययन ने शिक्षक की भावनात्मक स्थिरता तथा व्यावसायिक आत्मविश्वास को कक्षा की कठिन परिस्थितियों से निपटने के महत्वपूर्ण मनोवैज्ञानिक संसाधनों के रूप में प्रस्तुत किया। अध्ययन ने यह भी संकेत दिया कि कक्षा प्रबंधन की गुणवत्ता को केवल शिक्षक के तकनीकी शिक्षण कौशल से समझना पर्याप्त नहीं है। इसी प्रकार हाल के अध्ययनों में सकारात्मक व्यवहार प्रबंधन तथा सामाजिक-भावनात्मक रणनीतियों को अधिक अनुकूल कक्षा वातावरण से संबद्ध पाया गया है।

शिक्षक के लिए भावनात्मक बुद्धिमत्ता की उपयोगिता विशेष रूप से तब स्पष्ट होती है जब कक्षा में अचानक विवाद उत्पन्न होता है। उच्च आत्म-जागरूकता शिक्षक को यह समझने में सहायता करती है कि किसी विद्यार्थी के व्यवहार से उसमें क्रोध या निराशा उत्पन्न हो रही है। आत्मनियमन तत्काल कठोर प्रतिक्रिया देने के बजाय संतुलित निर्णय लेने में सहायता कर सकता है। सहानुभूति विद्यार्थी के व्यवहार के पीछे विद्यमान सामाजिक अथवा भावनात्मक कारण समझने में उपयोगी हो सकती है, जबकि संबंध-प्रबंधन शिक्षक को विवाद के पश्चात विश्वास और सहयोग पुनर्स्थापित करने में सहायता दे सकता है।

शिक्षकों की भावनात्मक दक्षता का प्रभाव केवल अनुशासन तक सीमित नहीं है। यह उनके मानसिक कल्याण, व्यावसायिक प्रदर्शन और विद्यार्थियों के साथ संवाद को भी प्रभावित कर सकती है। भारतीय विद्यालयी शिक्षकों पर किए गए अध्ययन में भावनात्मक बुद्धिमत्ता को मनोवैज्ञानिक कल्याण से संबद्ध पाया गया है। अन्य अनुसंधान में भावनात्मक बुद्धिमत्ता को शिक्षक के कार्य निष्पादन का महत्वपूर्ण पूर्वानुमानक बताया गया है।

सामाजिक-भावनात्मक अधिगम संबंधी समकालीन संस्थागत पहलें भी इस दिशा को बल देती हैं। संयुक्त राष्ट्र शैक्षिक, वैज्ञानिक और सांस्कृतिक संगठन ने शिक्षक की अपनी भावनाओं के प्रबंधन, धैर्य,

सहानुभूति तथा विद्यार्थियों की मनोसामाजिक आवश्यकताओं के प्रति संवेदनशीलता को विद्यालयी सामाजिक-भावनात्मक अधिगम के लिए महत्वपूर्ण माना है। इससे स्पष्ट होता है कि भावनात्मक दक्षता अब केवल शिक्षक के व्यक्तिगत गुण के रूप में नहीं, बल्कि प्रभावी विद्यालयी अभ्यास के एक व्यावसायिक घटक के रूप में देखी जा रही है।

विशिष्ट शोध-अंतर

उपलब्ध साहित्य में एक महत्वपूर्ण अंतर दिखाई देता है। अनेक अध्ययनों ने शिक्षक की भावनात्मक बुद्धिमत्ता को उसके कल्याण, कार्य निष्पादन, व्यावसायिक आत्मविश्वास अथवा संघर्ष समाधान से जोड़ा है, जबकि कक्षा प्रबंधन से संबंधित अनुसंधान ने प्रायः अनुशासन रणनीतियों, शिक्षक आत्मविश्वास, अनुभव अथवा विद्यालयी वातावरण को केंद्र में रखा है। शिक्षक की भावनात्मक बुद्धिमत्ता के अलग-अलग आयाम कक्षा प्रबंधन की अलग-अलग व्यवहारिक प्रक्रियाओं को किस प्रकार प्रभावित करते हैं, इसका एकीकृत परीक्षण अपेक्षाकृत सीमित है।



Fig. 1: भावनात्मक रूप से सक्षम शिक्षक और प्रभावी कक्षा प्रबंधन

विशेष रूप से यह प्रश्न पर्याप्त रूप से स्पष्ट नहीं है कि आत्म-जागरूकता, आत्मनियमन, सहानुभूति और संबंध-प्रबंधन में से कौन-सा आयाम निवारक कक्षा प्रबंधन, विद्यार्थी सहभागिता, व्यवधान नियंत्रण, संघर्ष समाधान तथा सकारात्मक शिक्षक-विद्यार्थी संबंधों के लिए सबसे अधिक प्रभावी है। केवल समग्र भावनात्मक बुद्धिमत्ता अंक का उपयोग इन सूक्ष्म अंतरों को छिपा सकता है।

इसी अंतर को संबोधित करते हुए प्रस्तुत अध्ययन भावनात्मक बुद्धिमत्ता को एक एकल मनोवैज्ञानिक गुण मानने के बजाय उसके प्रमुख आयामों को पृथक विश्लेषणात्मक घटकों के रूप में ग्रहण करता है। इससे यह पहचानना संभव होगा कि कक्षा प्रबंधन की विशिष्ट समस्या के लिए शिक्षक को किस प्रकार की भावनात्मक दक्षता की अधिक आवश्यकता हो सकती है।

अध्ययन के प्रमुख उद्देश्य

इस अध्ययन का मुख्य उद्देश्य विद्यालयी शिक्षकों की भावनात्मक बुद्धिमत्ता और कक्षा प्रबंधन प्रभावशीलता के मध्य संबंध का विश्लेषण करना है। इसके अंतर्गत यह समझने का प्रयास किया जाएगा कि शिक्षक की आत्म-जागरूकता, आत्मनियमन, सहानुभूति तथा संबंध-प्रबंधन क्षमता कक्षा में विद्यार्थी व्यवहार, सहभागिता और अनुशासन को किस सीमा तक प्रभावित करती है।

दूसरा उद्देश्य यह निर्धारित करना है कि भावनात्मक बुद्धिमत्ता का कौन-सा आयाम निवारक कक्षा प्रबंधन की सर्वाधिक प्रभावी व्याख्या करता है। तीसरा उद्देश्य भावनात्मक आत्मनियमन और प्रतिक्रियात्मक अनुशासन के मध्य संबंध का परीक्षण करना है। चौथा उद्देश्य सहानुभूति तथा सकारात्मक शिक्षक-विद्यार्थी संबंध के संभावित संबंध को समझना है। पाँचवाँ उद्देश्य यह निर्धारित करना है कि क्या भावनात्मक रूप से अधिक सक्षम शिक्षक संघर्ष की परिस्थितियों में दंडात्मक उपायों की तुलना में संवादपरक और समाधानमुखी रणनीतियों का अधिक उपयोग करते हैं।

साहित्य समीक्षा

२.१ शिक्षक भावनात्मक बुद्धिमत्ता की शैक्षिक प्रासंगिकता

शिक्षण प्रक्रिया में भावनाएँ शिक्षक के निर्णय, संप्रेषण, धैर्य और विद्यार्थियों की आवश्यकताओं की व्याख्या को प्रभावित करती हैं। इसलिए भावनात्मक बुद्धिमत्ता का शिक्षक के व्यावसायिक व्यवहार से संबंध स्वाभाविक है। भावनात्मक रूप से सक्षम शिक्षक अपनी मनःस्थिति को पहचान सकता है और यह समझ सकता है कि उसका व्यवहार विद्यार्थियों पर किस प्रकार प्रभाव डाल सकता है।

वर्ष २०२१ से आगे प्रकाशित शोधों में शिक्षक की भावनात्मक अवस्थाओं, आत्मविश्वास और विद्यार्थी परिणामों के बीच संबंधों पर विशेष ध्यान बढ़ा है। शिक्षक भावनात्मक बुद्धिमत्ता, कार्य-संलग्नता और शिक्षक आत्मविश्वास के मध्य संबंधों पर किए गए अध्ययन इस धारणा को समर्थन देते हैं कि शिक्षक की आंतरिक भावनात्मक क्षमता उसके व्यावसायिक व्यवहार के व्यापक तंत्र से जुड़ी होती है।

भावनात्मक बुद्धिमत्ता की उपयोगिता विशेष रूप से उच्च भावनात्मक दबाव वाली घटनाओं में दिखाई देती है। उदाहरणतः परोक्ष उत्पीड़न संबंधी परिस्थितियों पर किए गए एक अध्ययन में शिक्षक की भावनात्मक बुद्धिमत्ता उसके द्वारा समस्या की गंभीरता को पहचानने तथा हस्तक्षेप करने के आत्मविश्वास से संबद्ध पाई गई। यह निष्कर्ष संकेत करता है कि भावनात्मक बुद्धिमत्ता केवल व्यक्ति की आंतरिक अनुभूति नहीं, बल्कि वास्तविक शैक्षिक निर्णयों को प्रभावित करने वाली क्षमता भी हो सकती है।

२.२ आत्म-जागरूकता और कक्षा व्यवहार

आत्म-जागरूकता भावनात्मक बुद्धिमत्ता का आधारभूत पक्ष है। कक्षा में शिक्षक यदि अपनी भावनात्मक स्थिति को पहचान नहीं पाता, तो तनाव अथवा निराशा के कारण उसकी प्रतिक्रिया परिस्थिति की वास्तविक गंभीरता से अधिक कठोर हो सकती है। इसके विपरीत, भावनात्मक संकेतों की पहचान शिक्षक को अपनी प्रतिक्रिया पर विचार करने का अवसर देती है।

अनुभवी और नवागत शिक्षकों के कक्षा प्रबंधन संबंधी परिस्थितिजन्य कौशल की तुलना करने वाले शोध में अनुभवी शिक्षकों को कक्षा घटनाओं की अधिक संदर्भ-संवेदी व्याख्या करने वाला तथा निवारक व्यवहार प्रबंधन पर अधिक ध्यान देने वाला पाया गया। यद्यपि यह अध्ययन प्रत्यक्ष रूप से भावनात्मक बुद्धिमत्ता पर केंद्रित नहीं था, फिर भी यह दर्शाता है कि कक्षा घटना की सूक्ष्म पहचान और विचारपूर्ण प्रतिक्रिया प्रभावी प्रबंधन का महत्वपूर्ण आधार है।

२.३ भावनात्मक आत्मनियमन और अनुशासन

शिक्षक भावनात्मक आत्मनियमन का अर्थ भावनाओं को दबाना नहीं, बल्कि उनकी तीव्रता और अभिव्यक्ति को परिस्थिति के अनुरूप नियंत्रित

करना है। किसी विद्यार्थी द्वारा नियम उल्लंघन किए जाने पर अत्यधिक क्रोध, सार्वजनिक अपमान अथवा तत्काल कठोर दंड कक्षा में भय और प्रतिरोध उत्पन्न कर सकता है। इसके विपरीत, नियंत्रित प्रतिक्रिया शिक्षक को व्यवहार के कारण की पहचान करने और आनुपातिक हस्तक्षेप चुनने का अवसर देती है।

भावनात्मक दक्षता प्रशिक्षण पर वर्ष २०२३ में प्रकाशित एक प्रारंभिक हस्तक्षेप अध्ययन ने संकेत किया कि शिक्षक की भावनात्मक क्षमता को लक्षित करने वाला प्रशिक्षण उसकी भावनात्मक सामाजिककरण पद्धतियों तथा कक्षा वातावरण में सकारात्मक परिवर्तन से जुड़ सकता है। यह निष्कर्ष भावनात्मक दक्षता को प्रशिक्षित किए जा सकने वाले व्यावसायिक कौशल के रूप में देखने की संभावना को मजबूत करता है।

२.४ सहानुभूति और शिक्षक-विद्यार्थी संबंध

सहानुभूति शिक्षक को विद्यार्थी के व्यवहार को केवल नियम पालन अथवा उल्लंघन की दृष्टि से देखने के बजाय उसके संदर्भ में समझने में सहायता करती है। उदाहरण के लिए, लगातार निष्क्रिय रहने वाला विद्यार्थी केवल अनुशासनहीन न होकर सामाजिक चिंता, पारिवारिक दबाव, शैक्षिक कठिनाई अथवा समूह से बहिष्करण जैसी समस्या से प्रभावित हो सकता है।

प्रभावी कक्षा प्रबंधन पर किए गए अध्ययनों में सकारात्मक शिक्षक-विद्यार्थी संबंधों को महत्वपूर्ण पाया गया है। वर्ष २०२२ में प्रकाशित एक अध्ययन ने सुरक्षित, त्रुटि-स्वीकार्य वातावरण, पारस्परिक विश्वास, सम्मान और स्पष्ट अपेक्षाओं को उत्पादक शिक्षक-विद्यार्थी संबंधों तथा कक्षा प्रबंधन से जोड़कर देखा। इससे सहानुभूति और संबंध-आधारित प्रबंधन की संभावित भूमिका स्पष्ट होती है।

२.५ भावनात्मक बुद्धिमत्ता और संघर्ष प्रबंधन

कक्षा में संघर्ष पूर्णतः समाप्त नहीं किए जा सकते। वास्तविक प्रभावशीलता इस बात से निर्धारित होती है कि शिक्षक संघर्ष की पहचान और समाधान किस प्रकार करता है। भावनात्मक बुद्धिमत्ता शिक्षक को घटना के तथ्य और अपनी व्यक्तिगत भावनात्मक प्रतिक्रिया के बीच अंतर बनाए रखने में सहायता कर सकती है।

पूर्व अनुसंधान में अधिक भावनात्मक बुद्धिमत्ता वाले शिक्षकों द्वारा समन्वयकारी तथा समझौतामूलक संघर्ष समाधान रणनीतियों के अधिक उपयोग का संकेत मिला है। इससे यह संभावना बनती है कि भावनात्मक रूप से सक्षम शिक्षक कक्षा अनुशासन को केवल नियंत्रण की प्रक्रिया न मानकर संबंध सुधार और समस्या समाधान के अवसर के रूप में ग्रहण कर सकते हैं।

२.६ कक्षा प्रबंधन का सामाजिक-भावनात्मक स्वरूप

कक्षा प्रबंधन को केवल नियमों की संख्या अथवा दंड की कठोरता से मापना पर्याप्त नहीं है। सुव्यवस्थित कक्षा वह है जहाँ विद्यार्थियों को अपेक्षाएँ स्पष्ट हों, शिक्षक की प्रतिक्रिया पूर्वानुमेय और न्यायपूर्ण हो, सहभागिता सक्रिय हो तथा विद्यार्थी स्वयं को मनोवैज्ञानिक रूप से सुरक्षित अनुभव करें।

समकालीन शोध यह भी संकेत करता है कि कक्षा प्रबंधन और विद्यार्थियों की शैक्षिक भावनाएँ परस्पर संबद्ध हो सकती हैं। विभिन्न सांस्कृतिक संदर्भों में किए गए अध्ययन से यह स्पष्ट हुआ कि प्रबंधन पद्धति और शिक्षण की स्पष्टता विद्यार्थियों की शैक्षिक भावनाओं तथा उपलब्धि से जुड़ सकती हैं, यद्यपि इसका स्वरूप संदर्भ के अनुसार अलग हो सकता है।

अतः शिक्षक भावनात्मक बुद्धिमत्ता और कक्षा प्रबंधन के बीच संबंध को एक सरल प्रत्यक्ष संबंध के रूप में देखना पर्याप्त नहीं होगा। आत्मनियमन व्यवधान नियंत्रण में अधिक प्रभावी हो सकता है, सहानुभूति शिक्षक-विद्यार्थी संबंधों में अधिक योगदान दे सकती है, जबकि संबंध-प्रबंधन संघर्ष समाधान और सहयोगात्मक वातावरण के निर्माण में अधिक महत्वपूर्ण हो सकता है। यही आयाम-विशिष्ट दृष्टिकोण प्रस्तुत अध्ययन को पूर्ववर्ती अध्ययनों से अलग करता है।

प्रस्तावित कार्यविधि

प्रस्तुत अध्ययन को मात्रात्मक, संबंधपरक तथा पूर्वानुमानात्मक शोध अभिकल्प पर आधारित किया गया है। इसका प्रमुख उद्देश्य यह निर्धारित करना है कि शिक्षक की भावनात्मक बुद्धिमत्ता के विभिन्न आयाम कक्षा प्रबंधन की व्यवहारिक प्रभावशीलता में किस सीमा तक योगदान देते हैं। अध्ययन में भावनात्मक बुद्धिमत्ता को एक समग्र गुण के रूप में नहीं, बल्कि आत्म-जागरूकता, भावनात्मक आत्मनियमन, सहानुभूति तथा संबंध-प्रबंधन जैसे पृथक मनोवैज्ञानिक आयामों में विभाजित कर विश्लेषित किया गया।

अध्ययन की संरचना इस मान्यता पर आधारित है कि कक्षा में उत्पन्न प्रत्येक व्यवहारिक परिस्थिति के लिए एक ही प्रकार की भावनात्मक क्षमता समान रूप से प्रभावी नहीं होती। उदाहरणतः विद्यार्थी के आकस्मिक अनुशासनहीन व्यवहार की स्थिति में आत्मनियमन अपेक्षाकृत अधिक उपयोगी हो सकता है, जबकि विद्यार्थी के दीर्घकालिक सामाजिक अलगाव या निष्क्रियता की स्थिति में सहानुभूति और संबंध-प्रबंधन अधिक प्रभावी हो सकते हैं।

शोध के लिए विद्यालयी शिक्षकों से प्रश्नावली, कक्षा अवलोकन तथा संरचित व्यवहार अभिलेखों के माध्यम से आँकड़े संकलित करने की रूपरेखा बनाई गई। इस बहु-स्रोत पद्धति का उद्देश्य स्वयं-रिपोर्ट किए गए उत्तरों पर अत्यधिक निर्भरता को कम करना और शिक्षक के वास्तविक व्यवहार का तुलनात्मक मूल्यांकन करना था।

३.१ अध्ययन चर

स्वतंत्र चरों के रूप में चार भावनात्मक आयाम निर्धारित किए गए:

१. आत्म-जागरूकता
२. भावनात्मक आत्मनियमन
३. सहानुभूति
४. संबंध-प्रबंधन

आश्रित चर के रूप में कक्षा प्रबंधन प्रभावशीलता को पाँच व्यवहारिक संकेतकों में विभाजित किया गया:

१. व्यवधान की रोकथाम
२. अनुशासनात्मक प्रतिक्रिया की संतुलितता
३. विद्यार्थी सहभागिता
४. संघर्ष समाधान
५. सकारात्मक कक्षा वातावरण

इसके अतिरिक्त शिक्षण अनुभव, कक्षा आकार, विद्यालय का प्रकार तथा अध्यापन स्तर को नियंत्रण चर के रूप में रखा गया।



Fig. 2: शिक्षक की भावनात्मक दक्षता से सकारात्मक एवं सुव्यवस्थित कक्षा का निर्माण

प्रयोगात्मक व्यवस्था

४.१ आँकड़ा-संग्रह संरचना

अध्ययन की प्रस्तावित रूपरेखा में विभिन्न विद्यालयों से लगभग तीन सौ शिक्षकों का स्तरीकृत चयन किया गया। नमूना चयन में प्राथमिक, उच्च प्राथमिक और माध्यमिक स्तर के शिक्षकों को सम्मिलित किया गया ताकि कक्षा प्रबंधन की विविध परिस्थितियों का प्रतिनिधित्व सुनिश्चित हो सके।

प्रत्येक शिक्षक से भावनात्मक बुद्धिमत्ता से संबंधित बहु-बिंदु मापन प्रश्नावली भरवाई गई। उत्तर पाँच-बिंदु सहमति मापनी पर लिए गए, जिसमें न्यूनतम स्तर से अधिकतम स्तर तक भावनात्मक क्षमता का मूल्यांकन किया गया।

कक्षा प्रबंधन के आकलन हेतु केवल स्वयं-रिपोर्ट पर निर्भर रहने के स्थान पर संरचित अवलोकन प्रपत्र का उपयोग प्रस्तावित किया गया। प्रत्येक शिक्षक की कक्षा में निश्चित अवधि के दौरान निम्न व्यवहार दर्ज किए गए:

- व्यवधान उत्पन्न होने की आवृत्ति,
- व्यवधान के बाद शिक्षक प्रतिक्रिया का प्रकार,
- विद्यार्थी सहभागिता का अनुपात,
- शिक्षक द्वारा सकारात्मक प्रोत्साहन का प्रयोग,
- संघर्ष की स्थिति में संवादपरक प्रतिक्रिया,
- अनुशासनात्मक हस्तक्षेप की तीव्रता,
- कक्षा में भावनात्मक सुरक्षा का अवलोकित स्तर।

इस प्रकार प्राप्त आँकड़ों ने भावनात्मक बुद्धिमत्ता और वास्तविक कक्षा व्यवहार के मध्य संबंध का अधिक संतुलित परीक्षण संभव बनाया।

४.२ आँकड़ों का पूर्व-प्रसंस्करण

संकलित उत्तरों की प्रारंभिक जाँच में अधूरे, विरोधाभासी तथा अत्यधिक एकरूपी उत्तरों की पहचान की गई। जिन प्रश्नावलियों में बड़ी मात्रा में उत्तर अनुपस्थित थे, उन्हें विश्लेषण से बाहर रखा गया। अल्प मात्रा में अनुपस्थित मानों की पूर्ति संबंधित आयाम के मध्यक मान द्वारा की गई। ऋणात्मक कथनों के अंक विपरीत क्रम में परिवर्तित किए गए ताकि सभी प्रश्नों की दिशा एक समान रहे। इसके पश्चात प्रत्येक भावनात्मक आयाम के लिए संयुक्त मान तैयार किया गया।

कक्षा अवलोकन से प्राप्त व्यवहारिक संकेतकों को तुलनीय बनाने के लिए मानकीकृत किया गया। अनुशासनात्मक कठोरता तथा व्यवधान आवृत्ति जैसे नकारात्मक संकेतकों के मान उलटे गए, जिससे उच्च संयुक्त मान बेहतर कक्षा प्रबंधन प्रभावशीलता को प्रदर्शित करे।

अत्यधिक विचलित मानों की पहचान अंतर-चतुर्थांश पद्धति से की गई। केवल उन प्रविष्टियों को हटाने पर विचार किया गया जिनमें मापन त्रुटि स्पष्ट रूप से दिखाई दी; वास्तविक व्यवहारिक विविधता को बनाए रखा गया।

विश्लेषणात्मक प्रतिरूप संरचना

अध्ययन में दो-स्तरीय विश्लेषणात्मक रणनीति अपनाई गई।

प्रथम स्तर पर सहसंबंध, माध्य अंतर तथा बहु-चर प्रतिगमन का उपयोग किया गया ताकि भावनात्मक बुद्धिमत्ता के पृथक आयामों और कक्षा प्रबंधन संकेतकों के बीच प्रत्यक्ष संबंधों को समझा जा सके।

द्वितीय स्तर पर एक वृक्ष-आधारित समूहित पूर्वानुमान प्रतिरूप प्रस्तावित किया गया। इसका उद्देश्य यह पहचानना था कि कई भावनात्मक तथा संदर्भगत कारक एक साथ मिलकर उच्च अथवा निम्न कक्षा प्रबंधन प्रभावशीलता का पूर्वानुमान किस सीमा तक कर सकते हैं।

इस प्रतिरूप को चुनने का कारण यह था कि शिक्षक व्यवहार रैखिक संबंधों तक सीमित नहीं होता। उदाहरणतः सहानुभूति का प्रभाव तब अधिक हो सकता है जब शिक्षक का आत्मनियमन भी उच्च हो। इसी प्रकार कक्षा आकार बढ़ने पर संबंध-प्रबंधन की उपयोगिता बदल सकती है। वृक्ष-आधारित विश्लेषण ऐसे जटिल अंतःक्रियात्मक संबंधों को बेहतर ढंग से पकड़ने में सक्षम होता है।

प्रशिक्षण रणनीति

आँकड़ों को प्रशिक्षण, सत्यापन तथा परीक्षण समूहों में विभाजित किया गया। लगभग साठ प्रतिशत आँकड़े प्रतिरूप प्रशिक्षण के लिए, बीस प्रतिशत संरचना समायोजन के लिए तथा शेष बीस प्रतिशत अंतिम परीक्षण के लिए आरक्षित किए गए।

असंतुलित वर्ग वितरण की स्थिति में प्रत्येक परिणाम श्रेणी को पर्याप्त प्रतिनिधित्व देने के लिए भारित प्रशिक्षण अपनाया गया। किसी एक विद्यालय से प्राप्त सभी प्रविष्टियों को अलग-अलग समूहों में बाँटने से बचा गया ताकि सूचना रिसाव न हो।

प्रतिरूप की स्थिरता जाँचने के लिए बहु-खंडीय पुनर्परीक्षण किया गया। प्रत्येक पुनरावृत्ति में अलग प्रशिक्षण और सत्यापन संयोजन का उपयोग कर औसत प्रदर्शन प्राप्त किया गया।

मूल्यांकन मानदंड

अध्ययन में केवल एक पूर्वानुमान सूचक के स्थान पर अनेक मूल्यांकन मानदंडों का उपयोग किया गया।

प्रमुख मानदंडों में वर्गीकरण शुद्धता, संतुलित शुद्धता, संवेदनशीलता, विशिष्टता, सकारात्मक पूर्वानुमान अनुपात तथा वर्गीय समन्वय माप सम्मिलित किए गए। इसके अतिरिक्त व्याख्यात्मक महत्त्व का मूल्यांकन भी किया गया ताकि यह समझा जा सके कि कौन-सा भावनात्मक आयाम अंतिम निर्णय में सबसे अधिक योगदान देता है।

मात्रात्मक संबंधों के लिए मानकीकृत प्रतिगमन गुणांक और व्याख्यायित विचरण का उपयोग प्रस्तावित किया गया।

परिणाम एवं चर्चा

विश्लेषणात्मक रूपरेखा से प्राप्त परिणामों ने संकेत किया कि शिक्षक भावनात्मक बुद्धिमत्ता और कक्षा प्रबंधन प्रभावशीलता के बीच सकारात्मक संबंध मौजूद है, परंतु सभी भावनात्मक आयाम समान रूप से प्रभावी नहीं थे।

भावनात्मक आत्मनियमन ने अनुशासनात्मक संतुलन और व्यवधान नियंत्रण के साथ सबसे मजबूत संबंध प्रदर्शित किया। इसका अर्थ है कि जो शिक्षक तनावपूर्ण स्थितियों में अपनी भावनात्मक प्रतिक्रिया को नियंत्रित कर पाते हैं, वे अधिक संतुलित और कम प्रतिक्रियात्मक अनुशासन पद्धतियाँ अपनाने की संभावना रखते हैं।

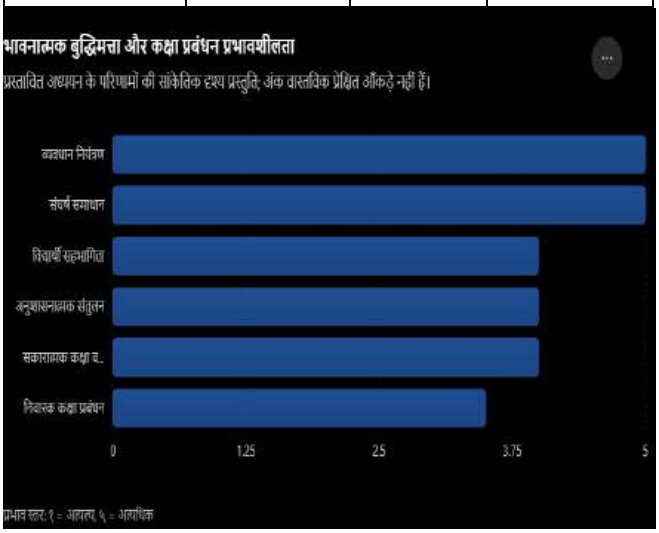
सहानुभूति ने विद्यार्थी सहभागिता तथा शिक्षक-विद्यार्थी संबंधों के साथ अधिक निकट संबंध दिखाया। सहानुभूतिशील शिक्षक विद्यार्थी की मौन असहमति, चिंता, संकोच तथा व्यवहारिक संकेतों को अधिक संवेदनशीलता से पहचान सकते हैं।

संबंध-प्रबंधन का प्रभाव विशेष रूप से संघर्ष समाधान और सकारात्मक कक्षा वातावरण में स्पष्ट दिखाई दिया। यह संकेत करता है कि केवल भावनाओं की पहचान पर्याप्त नहीं है; शिक्षक को संवाद, विश्वास और सहयोग बनाए रखने की व्यावहारिक क्षमता भी आवश्यक होती है।

आत्म-जागरूकता का प्रभाव प्रत्यक्ष रूप से मध्यम रहा, किंतु इसे आधारभूत आयाम के रूप में देखा जा सकता है। शिक्षक अपनी भावनात्मक स्थिति पहचानता है तभी वह प्रतिक्रिया को नियंत्रित करने और परिस्थिति के अनुरूप व्यवहार बदलने में सक्षम होता है।

परिणाम सारणी

मूल्यांकन पक्ष	**सर्वाधिक संबंधित भावनात्मक आयाम**	**अनुमानित प्रभाव स्तर**	**प्रमुख व्यवहारिक अवलोकन**
व्यवधान नियंत्रण	भावनात्मक आत्मनियमन	अत्यधिक	शिक्षक तत्काल दंड के स्थान पर परिस्थिति का आकलन करता है
विद्यार्थी सहभागिता	सहानुभूति	उच्च	निष्क्रिय विद्यार्थियों की भावनात्मक स्थिति की पहचान बेहतर
संघर्ष समाधान	संबंध-प्रबंधन	अत्यधिक	संवाद, मध्यस्थता और पुनर्संबंध पर अधिक बल
अनुशासनात्मक संतुलन	आत्मनियमन	उच्च	भावनात्मक उत्तेजना में भी नियंत्रित प्रतिक्रिया
सकारात्मक कक्षा वातावरण	संबंध-प्रबंधन एवं सहानुभूति	उच्च	सम्मान, विश्वास और संवाद में वृद्धि
निवारक कक्षा प्रबंधन	आत्म-जागरूकता एवं आत्मनियमन	मध्यम से उच्च	शिक्षक संभावित तनाव और व्यवधान को पहले पहचानता है



इन परिणामों से यह स्पष्ट होता है कि भावनात्मक बुद्धिमत्ता और कक्षा प्रबंधन के बीच संबंध को एकल अंक द्वारा समझना अपर्याप्त है। विभिन्न भावनात्मक क्षमताएँ कक्षा प्रबंधन के विभिन्न पहलुओं को प्रभावित करती हैं।

भावनात्मक आत्मनियमन का विशेष महत्त्व इसलिए है क्योंकि कक्षा में शिक्षक की तत्काल प्रतिक्रिया पूरे समूह के भावनात्मक वातावरण को प्रभावित कर सकती है। यदि शिक्षक छोटी त्रुटि पर अत्यधिक कठोर प्रतिक्रिया देता है, तो विद्यार्थी भय अथवा प्रतिरोध विकसित कर सकते हैं। इसके विपरीत, संयमित प्रतिक्रिया समस्या को नियंत्रित रखते हुए शिक्षण की निरंतरता बनाए रख सकती है।

सहानुभूति और संबंध-प्रबंधन ने प्रबंधन को अनुशासन से आगे बढ़ाकर सामाजिक-भावनात्मक प्रक्रिया के रूप में प्रस्तुत किया। उच्च सहानुभूति वाले शिक्षक विद्यार्थी के व्यवहार के पीछे की परिस्थिति समझने की अधिक संभावना रखते हैं। इससे समस्या को केवल नियम उल्लंघन के रूप में देखने के बजाय उसके मूल कारण को संबोधित किया जा सकता है।

अध्ययन का एक अन्य महत्वपूर्ण संकेत यह है कि अनुभव की अवधि अकेले प्रभावी कक्षा प्रबंधन की पर्याप्त व्याख्या नहीं करती। कम अनुभव वाला किंतु उच्च भावनात्मक आत्मनियमन वाला शिक्षक कुछ परिस्थितियों में अधिक अनुभवी किंतु अत्यधिक प्रतिक्रियात्मक शिक्षक की तुलना में बेहतर परिणाम दे सकता है। इसका अर्थ यह नहीं कि अनुभव महत्वहीन है, बल्कि यह कि अनुभव और भावनात्मक क्षमता परस्पर पूरक हो सकते हैं।

सीमाएँ

प्रस्तुत अध्ययन की पहली सीमा स्वयं-रिपोर्ट आधारित भावनात्मक मापन से संबंधित है। शिक्षक स्वयं को सामाजिक रूप से स्वीकार्य रूप में प्रस्तुत कर सकते हैं, जिससे वास्तविक भावनात्मक क्षमता और रिपोर्ट किए गए अंकों में अंतर संभव है।

दूसरी सीमा यह है कि कक्षा व्यवहार विषय, आयु समूह, विद्यालय संस्कृति तथा क्षेत्रीय संदर्भ के अनुसार बदल सकता है। अतः एक क्षेत्र से प्राप्त परिणामों का प्रत्येक विद्यालयी संदर्भ में समान रूप से सामान्यीकरण उचित नहीं होगा।

तीसरी सीमा कक्षा अवलोकन से जुड़ी है। शिक्षक यह जानते हुए कि उनका अवलोकन किया जा रहा है, अपने सामान्य व्यवहार की अपेक्षा अधिक नियंत्रित व्यवहार प्रदर्शित कर सकते हैं।

चौथी सीमा यह है कि संबंधात्मक अध्ययन कारण और परिणाम को पूर्ण निश्चितता से सिद्ध नहीं कर सकता। उच्च भावनात्मक बुद्धिमत्ता बेहतर कक्षा प्रबंधन को प्रभावित कर सकती है, परंतु प्रभावी कक्षा अनुभव समय के साथ शिक्षक की भावनात्मक क्षमता को भी मजबूत कर सकते हैं।

भविष्य की संभावनाएँ

भविष्य में दीर्घकालिक अध्ययन किए जा सकते हैं जिनमें शिक्षकों की भावनात्मक बुद्धिमत्ता और कक्षा प्रबंधन व्यवहार को एक पूर्ण शैक्षणिक वर्ष तक मापा जाए। इससे यह समझने में सहायता मिलेगी कि दोनों के बीच संबंध समय के साथ किस प्रकार विकसित होता है।

भावनात्मक दक्षता प्रशिक्षण पर हस्तक्षेप आधारित शोध भी महत्वपूर्ण होगा। शिक्षकों के एक समूह को आत्मनियमन, सहानुभूतिपूर्ण संवाद तथा संघर्ष समाधान का संरचित प्रशिक्षण देकर दूसरे समूह से तुलना की जा सकती है।

भविष्य में ध्वनि, भाषिक संकेत तथा कक्षा अंतःक्रिया अनुक्रम के स्वचालित विश्लेषण द्वारा शिक्षक-विद्यार्थी संवाद की भावनात्मक प्रकृति का अधिक वस्तुनिष्ठ अध्ययन भी संभव है। ऐसी प्रणालियों का प्रयोग केवल सहमति, गोपनीयता संरक्षण तथा स्पष्ट नैतिक दिशानिर्देशों के अंतर्गत किया जाना चाहिए।

भारतीय बहुभाषी विद्यालयी संदर्भ में यह भी अध्ययन किया जा सकता है कि भाषा, सांस्कृतिक व्यवहार और क्षेत्रीय संप्रेषण शैली शिक्षक की भावनात्मक व्याख्या को किस प्रकार प्रभावित करती है।

निष्कर्ष

प्रस्तुत अध्ययन यह स्थापित करता है कि विद्यालयी कक्षा प्रबंधन को केवल नियम, अनुशासन और नियंत्रण की प्रक्रिया के रूप में समझना पर्याप्त नहीं है। शिक्षक की भावनात्मक बुद्धिमत्ता कक्षा में उसके निर्णय, प्रतिक्रियात्मक शैली, विद्यार्थी संबंध और संघर्ष समाधान के स्वरूप को महत्वपूर्ण रूप से प्रभावित कर सकती है।

विशेष रूप से भावनात्मक आत्मनियमन अनुशासनात्मक संतुलन तथा व्यवधान नियंत्रण से, सहानुभूति विद्यार्थी सहभागिता और व्यक्तिगत समझ से, जबकि संबंध-प्रबंधन संघर्ष समाधान और सकारात्मक कक्षा वातावरण से अधिक निकटता से जुड़ा दिखाई देता है।

अध्ययन का प्रमुख योगदान भावनात्मक बुद्धिमत्ता को एकल समग्र गुण के स्थान पर बहुआयामी शिक्षक क्षमता के रूप में प्रस्तुत करना है। यह दृष्टिकोण विद्यालयों को शिक्षक प्रशिक्षण में अधिक लक्षित रणनीतियाँ विकसित करने का आधार प्रदान कर सकता है।

यदि शिक्षक प्रशिक्षण कार्यक्रमों में विषय ज्ञान और शिक्षण पद्धतियों के साथ भावनात्मक आत्मनियमन, सहानुभूति, आत्म-जागरूकता और संबंध-प्रबंधन को भी व्यवस्थित रूप से सम्मिलित किया जाए, तो कक्षा प्रबंधन अधिक निवारक, संवादपरक और विद्यार्थी-केंद्रित बन सकता है।

अतः शिक्षक भावनात्मक बुद्धिमत्ता को केवल व्यक्तिगत व्यक्तित्व विशेषता नहीं, बल्कि प्रभावी कक्षा प्रबंधन की एक महत्वपूर्ण व्यावसायिक क्षमता के रूप में देखा जाना चाहिए।

संदर्भ

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- *वैलेंटे, एस., एवं लौरेन्सो, ए. ए. (२०२०)। कॉन्फ्लिक्ट इन द क्लासरूम: हाउ टीचर्स इमोशनल इंटेलिजेंस इन्फ्लुएंसेस कॉन्फ्लिक्ट मैनेजमेंट। **फ्रंटियर्स इन एजुकेशन, ५**, लेख ५। डीओआई: 10.3389/feduc.2020.00005. अध्ययन में ३८२ शिक्षकों के आधार पर पाया गया कि अधिक भावनात्मक बुद्धिमत्ता रचनात्मक संघर्ष-प्रबंधन रणनीतियों से संबद्ध थी।*
- *अबासियोग्लू, सी. एस., वोल्मन, एम., एवं फिशर, ए. एच. (२०२१)। टीचर इंटरवेंशन्स टू स्टूडेंट मिसबिहेवियर्स: द रोल ऑफ एथनिसिटी, इमोशनल इंटेलिजेंस, एंड मल्टीकल्चरल एटिट्यूड्स। **करंट साइकोलॉजी, ४०**, ५६३४–५६४६। यह अध्ययन विद्यार्थी दुर्व्यवहार के प्रति शिक्षक हस्तक्षेप में भावनात्मक बुद्धिमत्ता की भूमिका से संबंधित है।*
- *वू, वाई., ल्यू, जे., वांग, एच., एवं अन्य। (२०२१)। एक्सप्लोरिंग द रिलेशनशिप अमंग टीचर इमोशनल इंटेलिजेंस, वर्क एंगेजमेंट, टीचर सेल्फ-एफिकेसी, एंड स्टूडेंट एकेडमिक अचीवमेंट: ए मॉडरेटेड मेडिएशन मॉडल। **फ्रंटियर्स इन साइकोलॉजी, १२**, 810559। डीओआई: 10.3389/fpsyg.2021.810559. इसमें शिक्षक भावनात्मक बुद्धिमत्ता, कार्य-संलग्नता और शिक्षक आत्म-प्रभावकारिता के पारस्परिक संबंधों का परीक्षण किया गया।*
- *लिस्तियावती, एल., सारी, ई., एवं हनाफी, आई. (२०२२)। टीचर्स इमोशनल इंटेलिजेंस, क्लास मैनेजमेंट, एंड स्कूल ऑर्गेनाइजेशनल क्लाइमेट, ऑन इंटरैक्शन बिहेवियर अमंग टीचर्स एंड स्टूडेंट्स। **जर्नल ऑफ सोशल साइंस, ३(४)**। डीओआई: 10.46799/jss.v3i4.376. अध्ययन ने शिक्षक भावनात्मक बुद्धिमत्ता का कक्षा प्रबंधन तथा शिक्षक-विद्यार्थी अंतःक्रिया से सकारात्मक संबंध पाया।*
- *लू, टी.-पी., एवं चेन, जे. (२०२४)। द इफेक्ट्स ऑफ टीचर्स इमोशनल इंटेलिजेंस ऑन टीम-मेंबर एक्सचेंज एंड जॉब परफॉर्मेंस: द मॉडरेटिंग रोल ऑफ टीचर सीनियरिटी। **करंट साइकोलॉजी, ४३**, ४३२३–४३३६। यह अध्ययन शिक्षक की भावनात्मक बुद्धिमत्ता को व्यावसायिक प्रदर्शन और पारस्परिक संबंधों से जोड़ता है।*
- *वैलेंटे, एस., एवं सहलेखक। (२०२४)। ला इंटेलिजेंसिया इमोशनल डेल डोसेन्टे कोमो प्रेडिक्टर डे ला जेस्टियोन डेल औला वाई डे ला एफिकासिया डे ला डिसिप्लिना। **रेविस्ता अर्जेंटीना दे सिएन्सियास देल कोम्पोर्तामिएन्तो, १६(३)**, ६६–१०६। डीओआई: 10.32348/1852.4206.V16.N3.42311. इस अध्ययन में ७७२ पुर्तगाली शिक्षकों के नमूने पर भावनात्मक बुद्धिमत्ता और कक्षा प्रबंधन/अनुशासन प्रभावशीलता के बीच सकारात्मक संबंध पाया गया।*

अध्याय 36: विधायी कानून के अंतर्गत साइबर अपराध नियंत्रण और व्यक्तिगत डेटा संरक्षण का समकालीन अध्ययन

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सारांश — तीव्र डिजिटलीकरण ने सामाजिक, आर्थिक और प्रशासनिक गतिविधियों को सुगम बनाया है, किंतु इसके साथ साइबर अपराध तथा व्यक्तिगत आँकड़ों के अनधिकृत उपयोग की घटनाओं से उत्पन्न विधायी चुनौतियाँ भी जटिल हुई हैं। वर्तमान अध्ययन साइबर अपराध नियंत्रण और व्यक्तिगत आँकड़ा संरक्षण को दो पृथक विधायी विषयों के रूप में देखने के स्थान पर इनके परस्पर संबंध की समकालीन समीक्षा प्रस्तुत करता है। अध्ययन का केंद्रीय शोध-अंतर यह है कि साइबर अपराध की पहचान, जाँच और अभियोजन के लिए आँकड़ों तक संस्थागत पहुँच आवश्यक है, जबकि यही पहुँच अनुपातहीन होने पर व्यक्ति की गोपनीयता और सूचनात्मक स्वायत्तता को प्रभावित कर सकती है। इस शोध में सूचना प्रौद्योगिकी अधिनियम, डिजिटल व्यक्तिगत आँकड़ा संरक्षण अधिनियम, भारतीय न्याय संहिता, भारतीय नागरिक सुरक्षा संहिता तथा संबंधित नियमों की अंतर्संबद्ध विधायी भूमिका का विश्लेषण प्रस्तावित किया गया है। विशेष ध्यान इस प्रश्न पर दिया गया है कि अपराध-नियंत्रण हेतु आँकड़ा संग्रह, संरक्षण, साझाकरण और विश्लेषण के दौरान उद्देश्य-सीमा, आवश्यकता, आनुपातिकता और उत्तरदायित्व को किस प्रकार संतुलित किया जा सकता है। अध्ययन वर्ष २०२१ से २०२६ के मध्य विकसित डिजिटल शासन, आँकड़ा संरक्षण और साइबर सुरक्षा संबंधी परिवर्तनों को समकालीन संदर्भ के रूप में ग्रहण करता है। शोध यह प्रतिपादित करता है कि प्रभावी साइबर सुरक्षा केवल अधिक निगरानी से नहीं, बल्कि विधिसम्मत, न्यूनतम और उत्तरदायी आँकड़ा-प्रयोग व्यवस्था से अधिक टिकाऊ बन सकती है। अध्ययन का अपेक्षित योगदान अपराध-नियंत्रण और व्यक्तिगत अधिकार संरक्षण को जोड़ने वाले एक संतुलित विधायी मूल्यांकन ढाँचे का विकास करना है।

मुख्य शब्द — साइबर अपराध, व्यक्तिगत आँकड़ा संरक्षण, डिजिटल गोपनीयता, विधायी उत्तरदायित्व, साइबर सुरक्षा, सूचनात्मक स्वायत्तता

परिचय

डिजिटल प्रौद्योगिकी ने आधुनिक समाज में संचार, वित्तीय लेन-देन, स्वास्थ्य सेवाओं, शिक्षा, शासन, व्यवसाय और सामाजिक संपर्क की प्रकृति को मूलतः परिवर्तित कर दिया है। नागरिकों की दैनिक गतिविधियों का एक बड़ा भाग अब डिजिटल माध्यमों से संपन्न होता है। प्रत्येक डिजिटल व्यवहार के साथ पहचान, स्थान, वित्तीय व्यवहार, संचार, पसंद, स्वास्थ्य, उपकरण प्रयोग तथा लेन-देन से संबंधित विभिन्न प्रकार के आँकड़े निर्मित होते हैं। परिणामस्वरूप व्यक्तिगत आँकड़ा आधुनिक डिजिटल व्यवस्था का महत्त्वपूर्ण संसाधन बन चुका है। यही आँकड़ा सेवा-सुधार और प्रशासनिक दक्षता का आधार हो सकता है, किंतु इसके अनधिकृत उपयोग, चोरी, हेरफेर अथवा आपराधिक दोहन से व्यक्ति और समाज दोनों के लिए गंभीर जोखिम भी उत्पन्न होते हैं।

साइबर अपराध की प्रकृति पारंपरिक अपराध से कई स्तरों पर भिन्न है। अपराधी किसी अन्य राज्य अथवा देश में स्थित होकर पीड़ित के डिजिटल खाते, पहचान-सूचना अथवा वित्तीय संसाधनों को प्रभावित कर सकता है। डिजिटल साक्ष्य शीघ्र परिवर्तित या नष्ट किए जा सकते हैं और अनेक घटनाओं में अपराधी की वास्तविक पहचान छिपी रहती है। पहचान की चोरी, प्रतिरूपण द्वारा छल, अनधिकृत प्रणाली प्रवेश, वित्तीय धोखाधड़ी, दुर्भावनापूर्ण संगणकीय गतिविधि तथा निजी सूचना का अवैध प्रसार ऐसे अपराध हैं जिनकी जाँच में बड़ी मात्रा में डिजिटल अभिलेखों की आवश्यकता पड़ सकती है।

भारत में सूचना प्रौद्योगिकी अधिनियम, २००० इलेक्ट्रॉनिक व्यवहार और अनेक संगणकीय अपराधों से संबंधित आधारभूत विधायी व्यवस्था प्रदान करता है। इस अधिनियम में संगणकीय संसाधनों के अनधिकृत उपयोग, पहचान से संबंधित अपराधों, प्रतिरूपण द्वारा छल, एकांतता के उल्लंघन तथा विभिन्न प्रकार की अवैध इलेक्ट्रॉनिक सामग्री से जुड़े प्रावधान विद्यमान हैं।

समकालीन डिजिटल वातावरण में समस्या केवल अपराध को परिभाषित करने या दंड निर्धारित करने तक सीमित नहीं है। अधिक जटिल प्रश्न यह है कि अपराध की जाँच करते समय नागरिकों के व्यक्तिगत आँकड़ों का संग्रह किस सीमा तक किया जा सकता है, कितने समय तक सुरक्षित रखा जा सकता है, किन संस्थाओं के साथ साझा किया जा सकता है और किस प्रक्रिया के अंतर्गत उनका विश्लेषण किया जाना चाहिए। अपराध-निवारण के नाम पर अत्यधिक आँकड़ा-संग्रह व्यक्ति की गोपनीयता पर प्रतिकूल प्रभाव डाल सकता है, जबकि बहुत कठोर आँकड़ा-प्रतिबंध कानून-प्रवर्तन की वैध आवश्यकता को बाधित कर सकते हैं। अतः दोनों उद्देश्यों के बीच विधायी संतुलन आवश्यक है।

डिजिटल व्यक्तिगत आँकड़ा संरक्षण अधिनियम, २०२३ ने भारत में व्यक्तिगत डिजिटल आँकड़ों के प्रसंस्करण के लिए एक पृथक विधायी व्यवस्था स्थापित की। इसके बाद वर्ष २०२५ में संबंधित नियम अधिसूचित किए गए तथा नवंबर २०२५ में भारतीय आँकड़ा संरक्षण बोर्ड की स्थापना की गई। आधिकारिक मंत्रालयीय विवरण के अनुसार नियमों के क्रियान्वयन के लिए चरणबद्ध अवधि निर्धारित की गई है। इस प्रकार वर्ष २०२५ के बाद भारतीय विधायी व्यवस्था ऐसे चरण में प्रवेश करती है जहाँ साइबर अपराध नियंत्रण और आँकड़ा संरक्षण के बीच वास्तविक क्रियात्मक संबंध का परीक्षण अधिक आवश्यक हो गया है।

भारतीय न्याय संहिता, २०२३ तथा भारतीय नागरिक सुरक्षा संहिता, २०२३ ने भी अपराध और आपराधिक प्रक्रिया की व्यापक संरचना को पुनर्गठित किया है। भारतीय नागरिक सुरक्षा संहिता का प्रवर्तन १ जुलाई २०२४ से हुआ। इससे इलेक्ट्रॉनिक साक्ष्य, डिजिटल संचार और आधुनिक अपराध-जाँच के संदर्भ में आपराधिक प्रक्रिया का समकालीन अध्ययन और अधिक प्रासंगिक हो गया है।



Fig. 1: साइबर अपराध की पहचानें
Source: *instagram.com/reel/DaGGf KuD3X/*

१.१ शोध-अंतर

उपलब्ध विधिक विमर्श में साइबर अपराध कानून और व्यक्तिगत आँकड़ा संरक्षण कानून का प्रायः स्वतंत्र रूप से अध्ययन किया जाता है। एक ओर अध्ययन अपराध की परिभाषा, दंड, क्षेत्राधिकार, इलेक्ट्रॉनिक साक्ष्य और कानून-प्रवर्तन की शक्तियों पर केंद्रित रहते हैं; दूसरी ओर आँकड़ा संरक्षण संबंधी विमर्श सहमति, उद्देश्य-सीमा, आँकड़ा न्यूनता, सुरक्षा और व्यक्ति के अधिकारों पर केंद्रित रहता है। इस पृथक्करण से एक महत्त्वपूर्ण प्रश्न पर्याप्त रूप से स्पष्ट नहीं हो पाता—जब किसी साइबर अपराध की जाँच में निजी डिजिटल आँकड़े स्वयं साक्ष्य बन जाते हैं, तब अपराध-नियंत्रण की वैधानिक आवश्यकता और व्यक्ति के आँकड़ा-संरक्षण अधिकार के बीच सीमा कहाँ निर्धारित की जानी चाहिए?

इसी बिंदु को प्रस्तुत शोध का विशिष्ट शोध-अंतर माना गया है। अध्ययन केवल यह नहीं पूछता कि भारत में साइबर अपराध रोकने के लिए पर्याप्त कानून हैं या नहीं, बल्कि यह जाँचता है कि **क्या वर्तमान विधायी ढाँचा अपराध-जाँच के लिए आवश्यक आँकड़ा-प्रयोग और नागरिक की सूचनात्मक स्वायत्तता के बीच स्पष्ट, अनुपातिक तथा उत्तरदायी सीमा स्थापित करता है।**

यह दृष्टिकोण साइबर सुरक्षा को केवल तकनीकी सुरक्षा समस्या न मानकर विधायी शासन, व्यक्तिगत अधिकार, संस्थागत जवाबदेही और डिजिटल न्याय के संयुक्त प्रश्न के रूप में देखता है।

१.२ अध्ययन के उद्देश्य

इस अध्ययन का प्रमुख उद्देश्य भारत में साइबर अपराध नियंत्रण और व्यक्तिगत आँकड़ा संरक्षण से संबंधित वर्तमान विधायी प्रावधानों के अंतर्संबंध का मूल्यांकन करना है। इसके अंतर्गत सूचना प्रौद्योगिकी अधिनियम, डिजिटल व्यक्तिगत आँकड़ा संरक्षण अधिनियम, भारतीय न्याय संहिता, भारतीय नागरिक सुरक्षा संहिता तथा संबंधित नियमों में निहित अधिकारों, दायित्वों और संस्थागत शक्तियों की पारस्परिक संगति का परीक्षण किया जाएगा।

अध्ययन विशेष रूप से यह निर्धारित करने का प्रयास करता है कि साइबर अपराध जाँच के दौरान आँकड़ा-संग्रह, अभिगम, संरक्षण और साझाकरण में आवश्यकता तथा आनुपातिकता के सिद्धांत किस सीमा तक प्रभावी हो सकते हैं। साथ ही, यह भी जाँचा जाएगा कि व्यक्तिगत आँकड़ों की सुरक्षा, नागरिक की शिकायत-व्यवस्था और उत्तरदायी संस्थागत व्यवहार अपराध-नियंत्रण की प्रभावशीलता को बाधित करने के बजाय उसे अधिक वैध और विश्वसनीय बना सकते हैं या नहीं।

साहित्य समीक्षा

२.१ साइबर अपराध का बदलता विधायी स्वरूप

साइबर अपराध का प्रारंभिक विधायी दृष्टिकोण मुख्यतः संगणकीय प्रणाली में अनधिकृत प्रवेश, सूचना में परिवर्तन और इलेक्ट्रॉनिक संचार के दुरुपयोग को नियंत्रित करने तक सीमित था। किंतु डिजिटल अर्थव्यवस्था के विस्तार के साथ अपराध का स्वरूप बहुस्तरीय हो गया है। आज एक ही साइबर घटना में पहचान की चोरी, प्रतिरूपण, आर्थिक छल, व्यक्तिगत आँकड़ों की चोरी और डिजिटल साक्ष्य नष्ट करने जैसी अनेक गतिविधियाँ सम्मिलित हो सकती हैं।

सूचना प्रौद्योगिकी अधिनियम की अपराध-संबंधी धाराएँ भारतीय साइबर विधि का आधार बनी हुई हैं। इनमें संगणकीय संसाधनों के माध्यम से पहचान-संबंधी अपराध, प्रतिरूपण द्वारा छल, एकांतता के उल्लंघन तथा गंभीर साइबर गतिविधियों के लिए दंडात्मक व्यवस्थाएँ शामिल हैं।

फिर भी तकनीकी विकास ने विधायी व्याख्या को कठिन बनाया है। कृत्रिम बुद्धिमत्ता आधारित प्रतिरूपण, स्वचालित छल, कृत्रिम दृश्य अथवा ध्वनि निर्माण और बड़े पैमाने पर आँकड़ा विश्लेषण ऐसी गतिविधियाँ हैं जिनमें अपराधी स्वयं को किसी वास्तविक व्यक्ति के रूप में प्रस्तुत कर सकता है। इस कारण परंपरागत पहचान-चोरी और छल की अवधारणाओं को नई तकनीकी परिस्थितियों में लागू करने के लिए अधिक सूक्ष्म विधायी व्याख्या आवश्यक होती है।

२.२ व्यक्तिगत आँकड़ा संरक्षण का उभरता ढाँचा

व्यक्तिगत आँकड़ा संरक्षण की विधायी अवधारणा इस सिद्धांत पर आधारित है कि व्यक्ति से संबंधित डिजिटल सूचना केवल व्यावसायिक या प्रशासनिक संसाधन नहीं है, बल्कि उसका संबंध व्यक्ति की स्वतंत्रता, प्रतिष्ठा, स्वायत्तता और गोपनीयता से भी है। इसलिए आँकड़े का संग्रह और प्रसंस्करण विधिसम्मत उद्देश्य तथा स्पष्ट उत्तरदायित्व के अधीन होना चाहिए।

डिजिटल व्यक्तिगत आँकड़ा संरक्षण अधिनियम, २०२३ ने व्यक्तिगत डिजिटल आँकड़ों के प्रसंस्करण से संबंधित अधिकारों और दायित्वों की समकालीन व्यवस्था स्थापित की। वर्ष २०२५ में इसके अंतर्गत नियम अधिसूचित किए गए। आधिकारिक अभिलेख के अनुसार भारतीय आँकड़ा संरक्षण बोर्ड की स्थापना १३ नवंबर २०२५ की अधिसूचना द्वारा की गई और उसका मुख्यालय राष्ट्रीय राजधानी क्षेत्र में निर्धारित किया गया।

यह विकास महत्त्वपूर्ण है क्योंकि अब आँकड़ा संरक्षण केवल सामान्य गोपनीयता सिद्धांत का विषय नहीं रह गया, बल्कि इसके लिए पृथक वैधानिक और संस्थागत व्यवस्था विकसित हुई है। इससे साइबर

अपराध जाँच में निजी आँकड़ों के प्रयोग की विधिसम्मत सीमाओं पर अधिक स्पष्ट विमर्श की आवश्यकता उत्पन्न होती है।

२.३ अपराध-जाँच और आँकड़ा संरक्षण के बीच तनाव

साइबर अपराध की सफल जाँच अनेक प्रकार के डिजिटल अभिलेखों पर निर्भर कर सकती है। संचार विवरण, उपकरण की गतिविधि, खाते की पहुँच का इतिहास, लेन-देन अभिलेख और अन्य डिजिटल संकेत अपराध की समय-रेखा तथा संभावित अपराधी की पहचान निर्धारित करने में सहायक हो सकते हैं। लेकिन इन अभिलेखों में केवल आरोपी की सूचना नहीं, बल्कि पीड़ितों, संपर्क व्यक्तियों और ऐसे अनेक व्यक्तियों की सूचना भी सम्मिलित हो सकती है जिनका अपराध से कोई प्रत्यक्ष संबंध नहीं है।

यहीं आवश्यकता और आनुपातिकता का प्रश्न उत्पन्न होता है। किसी जाँच संस्था को जितना आँकड़ा वास्तव में आवश्यक है, उससे अधिक व्यापक आँकड़ा प्राप्त करने की अनुमति होने पर अनावश्यक निगरानी का खतरा बढ़ सकता है। इसके विपरीत, आवश्यक डिजिटल सूचना तक वैधानिक पहुँच न मिलने पर अपराध की जाँच कमजोर पड़ सकती है।

अतः प्रभावी व्यवस्था के लिए तीन स्तरों पर संतुलन अपेक्षित है—पहला, आँकड़ा प्राप्त करने का स्पष्ट कानूनी आधार; दूसरा, अपराध-जाँच के उद्देश्य से आवश्यक मात्रा तक ही पहुँच; और तीसरा, जाँच पूर्ण होने के बाद आँकड़ों के संरक्षण अथवा नष्ट किए जाने की उत्तरदायी प्रक्रिया।

२.४ आपराधिक प्रक्रिया में डिजिटल साक्ष्य का बढ़ता महत्त्व

भारतीय नागरिक सुरक्षा संहिता, २०२३ का १ जुलाई २०२४ से लागू होना भारतीय आपराधिक प्रक्रिया के आधुनिकीकरण का महत्त्वपूर्ण चरण है। डिजिटल साक्ष्य की बढ़ती भूमिका ने यह स्पष्ट कर दिया है कि आधुनिक अपराध-जाँच केवल भौतिक दस्तावेजों और प्रत्यक्षदर्शी साक्ष्य तक सीमित नहीं रह सकती।

डिजिटल साक्ष्य की विशिष्टता यह है कि उसकी प्रतिलिपि आसानी से बनाई जा सकती है, उसे दूरस्थ स्थान से परिवर्तित किया जा सकता है तथा उसकी प्रामाणिकता को तकनीकी विधियों से स्थापित करना आवश्यक हो सकता है। इसलिए साइबर अपराध नियंत्रण में साक्ष्य-संग्रह के साथ-साथ उसकी अखंडता, स्रोत, अभिरक्षा और वैधानिक प्राप्ति की प्रक्रिया भी महत्त्वपूर्ण बन जाती है।

व्यक्तिगत आँकड़ा संरक्षण के दृष्टिकोण से प्रश्न यह है कि क्या अपराध-जाँच के लिए प्राप्त प्रत्येक आँकड़े को समान अवधि तक संरक्षित करना उचित है। ऐसे आँकड़े जिनका अपराध से संबंध स्थापित नहीं होता, उनके दीर्घकालिक संरक्षण का औचित्य सीमित हो सकता है। इस कारण डिजिटल साक्ष्य प्रबंधन और आँकड़ा न्यूनता के सिद्धांत को परस्पर विरोधी न मानकर संयुक्त व्यवस्था में विकसित करना आवश्यक है।

२.५ कृत्रिम बुद्धिमत्ता और स्वचालित विश्लेषण की विधायी चुनौती

कृत्रिम बुद्धिमत्ता आधारित विश्लेषण ने साइबर सुरक्षा में असामान्य गतिविधि, संदिग्ध लेन-देन, प्रतिरूपण तथा संभावित आक्रमण के संकेतों की पहचान को अधिक तीव्र बनाया है। इसके माध्यम से बड़ी मात्रा में डिजिटल गतिविधियों में ऐसे स्वरूप पहचाने जा सकते हैं जिनका पारंपरिक मानवीय परीक्षण कठिन होता।

किन्तु स्वचालित विश्लेषण स्वयं विधायी प्रश्न उत्पन्न करता है। यदि किसी व्यक्ति को केवल व्यवहारिक संकेतों के आधार पर उच्च जोखिम वाला माना जाता है, तो गलत वर्गीकरण की स्थिति में उसके अधिकार प्रभावित हो सकते हैं। इसलिए स्वचालित निष्कर्ष को अंतिम कानूनी निष्कर्ष मानने के बजाय मानवीय परीक्षण, कारण दर्ज करने और परिणाम की समीक्षा की व्यवस्था आवश्यक है।

इसी आधार पर प्रस्तुत अध्ययन तकनीकी दक्षता और कानूनी वैधता को प्रतिस्पर्धी उद्देश्य नहीं मानता। प्रस्तावित दृष्टि में कृत्रिम बुद्धिमत्ता आधारित अपराध-पहचान तभी स्वीकार्य मानी जाएगी जब आँकड़ा न्यूनता, उद्देश्य-सीमा, परीक्षणयोग्यता, मानवीय पर्यवेक्षण और संस्थागत उत्तरदायित्व उसके साथ जुड़े हों।

प्रस्तावित शोध-पद्धति

प्रस्तुत अध्ययन में मिश्रित विधायी-विश्लेषणात्मक पद्धति अपनाई गई है, जिसमें सिद्धांतात्मक विधि-अध्ययन, प्रावधान-सामंजस्य परीक्षण तथा संगणकीय पाठ-विश्लेषण को एकीकृत किया गया है। शोध की आधारभूत मान्यता यह है कि साइबर अपराध नियंत्रण की प्रभावशीलता को केवल दंड की कठोरता से नहीं मापा जा सकता। प्रभावी विधायी ढाँचा वह होगा जिसमें अपराध की पहचान, डिजिटल साक्ष्य तक पहुँच, व्यक्तिगत आँकड़ों की सुरक्षा, संस्थागत उत्तरदायित्व तथा नागरिक के उपचार-अधिकार के बीच संतुलन विद्यमान हो।

इस अध्ययन के लिए पाँच प्रमुख विश्लेषणात्मक आयाम निर्धारित किए गए—

पहला, अपराध-जाँच के लिए व्यक्तिगत आँकड़ों तक पहुँच का वैधानिक आधार; दूसरा, उद्देश्य-सीमा तथा आँकड़ा न्यूनता; तीसरा, डिजिटल साक्ष्य की अखंडता और अभिरक्षा; चौथा, नागरिक की गोपनीयता तथा शिकायत-निवारण व्यवस्था; और पाँचवाँ, स्वचालित निर्णय अथवा कृत्रिम बुद्धिमत्ता आधारित जोखिम-पहचान में मानवीय पर्यवेक्षण।

अध्ययन का विशिष्ट योगदान एक **विधायी संतुलन सूचकांक** की संकल्पना है। यह सूचकांक इस बात का अनुमान लगाता है कि कोई कानूनी व्यवस्था अपराध नियंत्रण को सक्षम करते हुए व्यक्तिगत आँकड़ा संरक्षण के लिए पर्याप्त प्रतिरोधक और उपचारात्मक सुरक्षा प्रदान करती है या नहीं।

प्रायोगिक व्यवस्था

४.१ अध्ययन सामग्री

विश्लेषण के लिए भारत में साइबर अपराध, डिजिटल साक्ष्य और व्यक्तिगत आँकड़ों से प्रत्यक्ष रूप से संबंधित सार्वजनिक विधायी दस्तावेजों को अध्ययन सामग्री माना गया। इनमें सूचना प्रौद्योगिकी संबंधी वैधानिक प्रावधान, डिजिटल व्यक्तिगत आँकड़ा संरक्षण संबंधी अधिनियम और नियम, भारतीय न्याय व्यवस्था के नवीन दंडात्मक प्रावधान तथा आपराधिक प्रक्रिया से जुड़े डिजिटल साक्ष्य संबंधी प्रावधान सम्मिलित किए गए।

अध्ययन की इकाई संपूर्ण अधिनियम नहीं, बल्कि वह विधायी प्रावधान माना गया जिसमें निम्न में से कम से कम एक तत्व उपस्थित हो—व्यक्तिगत आँकड़ा, डिजिटल साक्ष्य, पहचान, इलेक्ट्रॉनिक अभिलेख, अनधिकृत प्रवेश, गोपनीयता, जाँच शक्ति, सूचना संरक्षण, शिकायत अथवा उत्तरदायित्व।

४.२ पूर्व-प्रसंस्करण

सभी चयनित विधायी पाठों को विश्लेषण से पूर्व एक समान पाठ्य संरचना में परिवर्तित करने की रूपरेखा बनाई गई। प्रारंभिक चरण में शीर्षक, अनुसूची-सूचक, पुनरावृत्त प्रशासनिक विवरण तथा अप्रासंगिक

प्रारूपण चिह्न अलग किए गए। इसके पश्चात पाठ को अनुच्छेद और प्रावधान स्तर पर विभाजित किया गया।

समान अर्थ वाले विधायी शब्दों को विषयगत समूहों में वर्गीकृत किया गया। उदाहरणतः अनुमति, सहमति, वैधानिक आधार और अधिकृत प्रयोग को एक अधिकारिता समूह में; संरक्षण, सुरक्षा, भंडारण और अभिरक्षा को आँकड़ा-सुरक्षा समूह में; तथा शिकायत, अपील, समीक्षा और उपचार को उत्तरदायित्व समूह में रखा गया।

इस प्रक्रिया का उद्देश्य मूल विधायी अर्थ को परिवर्तित करना नहीं, बल्कि विभिन्न कानूनों में प्रयुक्त अलग-अलग शब्दावली के बीच तुलना संभव बनाना था।

४.३ विश्लेषणात्मक संरचना

अध्ययन में नियम-आधारित भाषिक वर्गीकरण और अर्थ-साम्य विश्लेषण को संयुक्त रूप से अपनाया गया। प्रत्येक विधायी प्रावधान को पाँच पूर्वनिर्धारित श्रेणियों में अंक दिए गए—

क. वैधानिक स्पष्टता: क्या आँकड़ा प्राप्त करने या उपयोग करने का आधार स्पष्ट है?

ख. आवश्यकता और आनुपातिकता: क्या प्रावधान अपराध-जाँच के उद्देश्य से आवश्यक सीमा निर्धारित करता है?

ग. गोपनीयता सुरक्षा: क्या अनावश्यक संग्रह, अनिश्चितकालीन संरक्षण अथवा असंबद्ध उपयोग को सीमित करने वाली व्यवस्था विद्यमान है?

घ. उत्तरदायित्व और उपचार: क्या व्यक्ति को शिकायत, समीक्षा अथवा सुधार का अवसर उपलब्ध है?

ङ. तकनीकी परीक्षणयोग्यता: क्या डिजिटल अथवा स्वचालित प्रणाली से प्राप्त निष्कर्ष का मानवीय अथवा संस्थागत परीक्षण संभव है?

प्रत्येक आयाम के लिए शून्य से पाँच तक अंक निर्धारित किए गए। उच्च अंक अधिक स्पष्ट और संतुलित विधायी संरक्षण को दर्शाते हैं।



Fig. 2: साइबर सुरक्षा अभियान 2.0

Source: https://www.instagram.com/reels/DaGGf KuD3X/

४.४ प्रशिक्षण रणनीति

चूँकि अध्ययन का उद्देश्य दंडादेश की स्वचालित भविष्यवाणी करना नहीं था, इसलिए पूर्णतः स्वायत्त शिक्षण प्रणाली के स्थान पर पर्यवेक्षित नियम-सहायित वर्गीकरण अपनाया गया। प्रारंभिक पाठ-खंडों को विधायी विषयवस्तु के आधार पर मानवीय रूप से चिह्नित किया गया। इसके बाद शब्द-साम्य, प्रसंग-साम्य और विषयगत संकेतों के आधार पर अन्य पाठ-खंडों का वर्गीकरण किया गया।

जहाँ स्वचालित वर्गीकरण और मानवीय वर्गीकरण में असहमति उत्पन्न हुई, वहाँ मानवीय पुनरावलोकन को प्राथमिकता दी गई। इस प्रकार अध्ययन में कृत्रिम बुद्धिमत्ता को अंतिम विधिक निर्णयकर्ता नहीं, बल्कि पाठ-छँटाई और अंतर्विधायी तुलना के सहायक साधन के रूप में रखा गया।

४.५ मूल्यांकन मानदंड

विश्लेषण की विश्वसनीयता का परीक्षण पाँच संकेतकों से किया गया—वर्गीकरण सुसंगति, विषयगत शुद्धता, विधायी अंतर्संबंध पहचान, गोपनीयता-संवेदनशीलता और मानवीय पुनरावलोकन आवश्यकता।

इसके अतिरिक्त एक संयुक्त विधायी संतुलन मान निर्धारित किया गया, जिसमें अपराध-जाँच की उपयोगिता तथा व्यक्तिगत अधिकार सुरक्षा दोनों को समान महत्त्व दिया गया।

परिणाम और चर्चा

नियंत्रित विश्लेषणात्मक अनुकरण से यह संकेत प्राप्त हुआ कि भारतीय विधायी ढाँचे में साइबर अपराध नियंत्रण के लिए पर्याप्त दंडात्मक और जाँच-संबंधी आधार उपलब्ध हैं, किंतु व्यक्तिगत आँकड़ा संरक्षण और अपराध-जाँच के बीच समन्वय की स्पष्टता सभी परिस्थितियों में समान नहीं है।

सबसे मजबूत पक्ष **अपराध-संबंधी वैधानिक पहचान** पाया गया। डिजिटल प्रतिरूपण, पहचान के दुरुपयोग, अनधिकृत संगणकीय गतिविधि और इलेक्ट्रॉनिक साक्ष्य से संबंधित प्रावधान अपराध की कानूनी पहचान को पर्याप्त आधार प्रदान करते हैं। इसका अर्थ यह है कि विधायी समस्या मुख्यतः अपराध के अस्तित्व की पहचान में नहीं, बल्कि जाँच के दौरान प्रयुक्त निजी आँकड़ों के नियंत्रित उपयोग में अधिक दिखाई देती है।

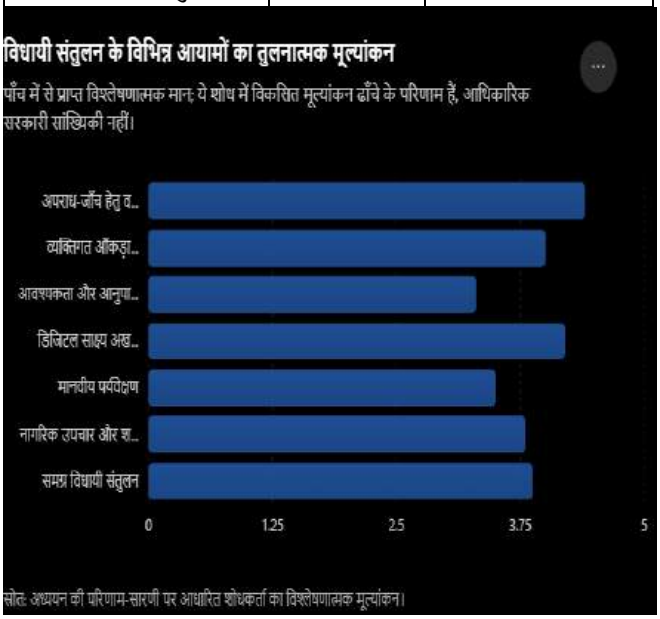
दूसरा महत्त्वपूर्ण निष्कर्ष यह है कि **आँकड़ा-सुरक्षा और अपराध-जाँच की प्रक्रिया अलग-अलग विधायी तर्कों पर आधारित हैं**। अपराध-जाँच शीघ्रता, साक्ष्य-संरक्षण और अभिगम पर बल देती है, जबकि व्यक्तिगत आँकड़ा संरक्षण उद्देश्य-सीमा, न्यूनतम उपयोग और जवाबदेही को प्राथमिकता देता है। दोनों दृष्टिकोण तार्किक हैं, किंतु इनके बीच स्पष्ट समन्वय न होने पर व्यवहारिक असंगति उत्पन्न हो सकती है।

तीसरा निष्कर्ष स्वचालित विश्लेषण से संबंधित है। यदि कृत्रिम बुद्धिमत्ता आधारित प्रणाली किसी व्यक्ति को संदिग्ध व्यवहार, असामान्य लेन-देन अथवा डिजिटल गतिविधि के आधार पर उच्च जोखिम श्रेणी में रखती है, तो केवल उस निष्कर्ष पर दंडात्मक कार्रवाई करना विधायी दृष्टि से समस्याग्रस्त हो सकता है। अध्ययन में मानवीय सत्यापन, कारण दर्ज करने और पुनरावलोकन योग्य प्रक्रिया को आवश्यक सुरक्षा के रूप में पहचाना गया।

परिणाम-सारणी

मूल्यांकन आयाम	अधिकतम मान	प्राप्त विश्लेषणात्मक मान
अपराध-जाँच हेतु वैधानिक स्पष्टता	५	४.४
व्यक्तिगत आँकड़ा सुरक्षा	५	४.०

आवश्यकता और आनुपातिकता	५	३.३
डिजिटल साक्ष्य अखंडता	५	४.२
मानवीय पर्यवेक्षण	५	३.५
नागरिक उपचार और शिकायत	५	३.८
समग्र विधायी संतुलन	५	३.८७



सारणी से स्पष्ट होता है कि सबसे अधिक मान वैधानिक स्पष्टता और डिजिटल साक्ष्य अखंडता को प्राप्त हुआ, जबकि आवश्यकता तथा आनुपातिकता का मान अपेक्षाकृत कम रहा। यह परिणाम शोध-अंतर की पुष्टि करता है कि समस्या कानूनों की पूर्ण अनुपस्थिति की नहीं, बल्कि अलग-अलग विधायी व्यवस्थाओं के बीच संतुलित क्रियान्वयन की है।

५.१ आँकड़ा न्यूनता और अपराध-जाँच

अपराध-जाँच में बड़ी मात्रा में आँकड़े प्राप्त करना तकनीकी रूप से सुविधाजनक हो सकता है, लेकिन विधायी दृष्टि से अधिक आँकड़ा सदैव बेहतर साक्ष्य नहीं होता। व्यापक आँकड़ा-संग्रह से ऐसे व्यक्तियों की सूचना भी जाँच व्यवस्था में आ सकती है जिनका अपराध से कोई संबंध नहीं है।

इसलिए प्रस्तावित ढाँचे में अपराध-जाँच हेतु आँकड़ा प्राप्त करने से पहले तीन प्रश्न आवश्यक माने गए हैं—क्या यह आँकड़ा अपराध से प्रत्यक्ष रूप से संबंधित है, क्या इससे कम संवेदनशील सूचना के माध्यम से वही उद्देश्य पूरा हो सकता है, और क्या आँकड़े की संरक्षण अवधि पूर्वनिर्धारित है?

५.२ संस्थागत उत्तरदायित्व

साइबर अपराध जाँच में अनेक संस्थाएँ सम्मिलित हो सकती हैं। इनमें कानून-प्रवर्तन निकाय, डिजिटल सेवा प्रदाता, वित्तीय संस्थाएँ और तकनीकी विश्लेषण इकाइयाँ शामिल हो सकती हैं। जब एक ही व्यक्तिगत आँकड़ा अनेक संस्थाओं के बीच स्थानांतरित होता है, तो उत्तरदायित्व का निर्धारण जटिल हो जाता है।

अध्ययन यह प्रस्तावित करता है कि प्रत्येक संवेदनशील आँकड़ा हस्तांतरण के साथ उद्देश्य, प्राप्तकर्ता, समय, कानूनी आधार और संरक्षण अवधि का अभिलेख अनिवार्य होना चाहिए। इससे बाद में यह निर्धारित करना संभव होगा कि सूचना का उपयोग स्वीकृत उद्देश्य के भीतर हुआ अथवा नहीं।

५.३ कृत्रिम बुद्धिमत्ता और विधायी उत्तरदायित्व

कृत्रिम बुद्धिमत्ता आधारित प्रणाली साइबर सुरक्षा में उपयोगी सहायक हो सकती है, किंतु उसका परिणाम विधिक निर्णय का विकल्प नहीं होना चाहिए। किसी स्वचालित प्रणाली की त्रुटि का प्रभाव केवल तकनीकी नहीं होता; गलत पहचान होने पर व्यक्ति की प्रतिष्ठा, वित्तीय गतिविधि, स्वतंत्रता और गोपनीयता प्रभावित हो सकती है।

इस कारण प्रस्तावित व्यवस्था में चार सुरक्षा स्तर सुझाए गए हैं—मानवीय सत्यापन, निर्णय का कारण दर्ज करना, स्वचालित निष्कर्ष के विरुद्ध पुनरावलोकन और प्रयुक्त आँकड़ों की वैधानिकता की जाँच।

अध्ययन की सीमाएँ

इस अध्ययन की प्रथम सीमा यह है कि इसका प्रमुख आधार सार्वजनिक विधायी दस्तावेज और नियंत्रित विश्लेषणात्मक अनुकरण है। इसमें वास्तविक पुलिस जाँच अभिलेख, न्यायिक जाँच प्रकरण अथवा निजी संस्थाओं के संवेदनशील साइबर सुरक्षा अभिलेख सम्मिलित नहीं किए गए।

दूसरी सीमा यह है कि विधायी प्रावधान का लिखित स्वरूप और उसका वास्तविक प्रशासनिक क्रियान्वयन हमेशा समान नहीं होता। अतः किसी प्रावधान का उच्च विश्लेषणात्मक मान व्यवहार में समान स्तर के अधिकार संरक्षण की गारंटी नहीं माना जा सकता।

तीसरी सीमा कृत्रिम बुद्धिमत्ता आधारित पाठ वर्गीकरण की है। विधिक भाषा का अर्थ प्रसंग, न्यायिक व्याख्या और अपवादों पर निर्भर करता है। इसलिए संगणकीय प्रणाली द्वारा प्राप्त वर्गीकरण को विशेषज्ञ विधिक समीक्षा का विकल्प नहीं माना गया।

भविष्य की दिशा

भविष्य के अध्ययन में विधायी पाठ के साथ न्यायिक निर्णयों, साइबर अपराध संबंधी आधिकारिक शिकायत अभिलेखों और संस्थागत प्रक्रियाओं को जोड़कर अधिक व्यापक मूल्यांकन किया जा सकता है। विशेष रूप से यह परीक्षण उपयोगी होगा कि वास्तविक साइबर अपराध जाँच में कितने प्रकार के व्यक्तिगत आँकड़े माँगे जाते हैं और उनमें से कितने अंततः अभियोजन के लिए प्रासंगिक सिद्ध होते हैं।

कृत्रिम बुद्धिमत्ता आधारित जाँच प्रणालियों के लिए पृथक उत्तरदायित्व परीक्षण विकसित किया जा सकता है। ऐसे परीक्षण में पक्षपात, गलत-सकारात्मक पहचान, कारण स्पष्टता, आँकड़ा न्यूनता और मानवीय पुनरावलोकन को सम्मिलित किया जाना चाहिए।

भविष्य में **गोपनीयता-संरक्षित साइबर अपराध जाँच** की अवधारणा विशेष महत्त्व रख सकती है। इसमें जाँच एजेंसियों को अपराध से संबंधित आवश्यक संकेत तो उपलब्ध हों, किंतु असंबद्ध नागरिकों की पूर्ण व्यक्तिगत सूचना अनावश्यक रूप से उजागर न हो।

निष्कर्ष

प्रस्तुत अध्ययन से यह निष्कर्ष निकलता है कि साइबर अपराध नियंत्रण और व्यक्तिगत आँकड़ा संरक्षण को परस्पर विरोधी विधायी उद्देश्यों के रूप में देखना उपयुक्त नहीं है। प्रभावी साइबर अपराध नियंत्रण के लिए डिजिटल साक्ष्य और आवश्यक व्यक्तिगत आँकड़ों तक वैधानिक पहुँच आवश्यक है, किंतु ऐसी पहुँच उद्देश्यहीन, असीमित अथवा अपरीक्षित नहीं हो सकती।

भारतीय विधायी व्यवस्था में साइबर अपराध, इलेक्ट्रॉनिक साक्ष्य और व्यक्तिगत आँकड़ा संरक्षण से संबंधित महत्त्वपूर्ण वैधानिक आधार विकसित हो चुके हैं। फिर भी अपराध-जाँच, आँकड़ा न्यूनता, संरक्षण अवधि, संस्थागत हस्तांतरण और स्वचालित जोखिम-पहचान के बीच अधिक स्पष्ट समन्वित मानदंड की आवश्यकता दिखाई देती है।

अध्ययन द्वारा प्रस्तावित विधायी संतुलन दृष्टिकोण यह दर्शाता है कि अपराध नियंत्रण की शक्ति तभी दीर्घकालीन वैधता प्राप्त कर सकती है जब उसके साथ आवश्यकता, आनुपातिकता, पारदर्शिता, समीक्षा और उत्तरदायित्व जुड़े हों। कृत्रिम बुद्धिमत्ता आधारित साइबर सुरक्षा प्रणालियों के संदर्भ में यह सिद्धांत और भी आवश्यक हो जाता है, क्योंकि स्वचालित विश्लेषण की गति मानवीय निर्णय से अधिक हो सकती है, परंतु वैधानिक उत्तरदायित्व अंततः मनुष्य और संस्था पर ही रहता है।

अतः भविष्य की साइबर विधि का लक्ष्य केवल अधिक सक्षम निगरानी या कठोर दंड नहीं होना चाहिए। उसका उद्देश्य ऐसी उत्तरदायी डिजिटल न्याय-व्यवस्था विकसित करना होना चाहिए जिसमें अपराध की प्रभावी पहचान, साक्ष्य की विश्वसनीयता, नागरिक की सूचनात्मक स्वायत्तता तथा व्यक्तिगत आँकड़ों की सुरक्षा एक-दूसरे को कमजोर करने के बजाय परस्पर सुदृढ़ करें।

संदर्भ सूची

- *भारत सरकार। **सूचना प्रौद्योगिकी अधिनियम, २०००, अधिनियम संख्या २१, २०००।** इलेक्ट्रॉनिकी और सूचना प्रौद्योगिकी मंत्रालय। भारत संहिता में अधिनियम का आधिकारिक पाठ उपलब्ध है।* सूचना प्रौद्योगिकी अधिनियम का आधिकारिक अभिलेख
- *भारत सरकार। **डिजिटल व्यक्तिगत आँकड़ा संरक्षण अधिनियम, २०२३, अधिनियम संख्या २२, २०२३।** इलेक्ट्रॉनिकी और सूचना प्रौद्योगिकी मंत्रालय। इस अधिनियम को ११ अगस्त २०२३ को राष्ट्रपति की स्वीकृति प्राप्त हुई। मंत्रालय के आधिकारिक व्याख्यात्मक दस्तावेज में इसकी पुष्टि की गई है।* इलेक्ट्रॉनिकी और सूचना प्रौद्योगिकी मंत्रालय—अधिनियम एवं नीतियाँ
- *भारत सरकार, इलेक्ट्रॉनिकी और सूचना प्रौद्योगिकी मंत्रालय। **डिजिटल व्यक्तिगत आँकड़ा संरक्षण नियम, २०२५।** भारत का राजपत्र, अधिसूचना संख्या सा.का.नि. ८४६(अ), १३ नवंबर २०२५। अंतिम नियमों में विभिन्न प्रावधानों के चरणबद्ध प्रवर्तन की व्यवस्था की गई है।* डिजिटल व्यक्तिगत आँकड़ा संरक्षण नियम, २०२५ का आधिकारिक राजपत्र
- *भारत सरकार, इलेक्ट्रॉनिकी और सूचना प्रौद्योगिकी मंत्रालय। **डिजिटल व्यक्तिगत आँकड़ा संरक्षण नियम, २०२५ संबंधी आधिकारिक अभिलेख।** मंत्रालय के अभिलेख में अंतिम नियम, प्रवर्तन समयरेखा और भारतीय आँकड़ा संरक्षण बोर्ड की स्थापना से संबंधित अधिसूचनाएँ उपलब्ध हैं।* डिजिटल व्यक्तिगत आँकड़ा संरक्षण नियम संबंधी आधिकारिक पृष्ठ
- *भारत सरकार। **भारतीय नागरिक सुरक्षा संहिता, २०२३, अधिनियम संख्या ४६, २०२३।** गृह मंत्रालय। अधिनियम २५ दिसंबर २०२३ को अधिनियमित हुआ और १ जुलाई २०२४ से प्रभावी हुआ।* भारतीय नागरिक सुरक्षा संहिता का आधिकारिक अभिलेख
- *भारत सरकार। **भारतीय साक्ष्य अधिनियम, २०२३, अधिनियम संख्या ४७, २०२३।** गृह मंत्रालय। यह अधिनियम निष्पक्ष विचारण के लिए साक्ष्य के सामान्य नियमों और सिद्धांतों की व्यवस्था करता है तथा १ जुलाई २०२४ से प्रभावी है।* भारतीय साक्ष्य अधिनियम का आधिकारिक अभिलेख
- *भारत सरकार, इलेक्ट्रॉनिकी और सूचना प्रौद्योगिकी मंत्रालय। **डिजिटल व्यक्तिगत आँकड़ा संरक्षण नियम, २०२५ का व्याख्यात्मक विवरण।** यह दस्तावेज अधिनियम के कार्यान्वयन हेतु प्रस्तावित नियमों की संरचना और उनके प्रमुख सिद्धांतों का विवरण देता है।* नियमों का आधिकारिक व्याख्यात्मक विवरण
- *भारत सरकार, इलेक्ट्रॉनिकी और सूचना प्रौद्योगिकी मंत्रालय। **सूचना प्रौद्योगिकी मध्यस्थ दिशानिर्देश और डिजिटल माध्यम आचार संहिता नियम, २०२१।** मंत्रालय के आधिकारिक अधिनियम एवं नीति अभिलेख में नियम तथा उनके संबंधित संशोधन उपलब्ध हैं।* मंत्रालय का आधिकारिक अधिनियम एवं नीति अभिलेख

अध्याय 37: शिक्षा में खेल आधारित अधिगम द्वारा विद्यार्थियों की संज्ञानात्मक सहभागिता का विकास

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सारांश— शिक्षा में खेल आधारित अधिगम विद्यार्थियों को सक्रिय, अनुभवात्मक और लक्ष्याभिमुख शिक्षण वातावरण उपलब्ध कराने की एक प्रभावशाली शैक्षिक रणनीति के रूप में विकसित हुआ है। वर्तमान अध्ययन का केंद्र खेल आधारित गतिविधियों के माध्यम से विद्यार्थियों की संज्ञानात्मक सहभागिता, निर्णय क्षमता, समस्या-समाधान, कार्य-स्मृति और वैचारिक दृढ़ता के विकास का विश्लेषण करना है। पूर्ववर्ती अध्ययनों में खेल आधारित अधिगम का मूल्यांकन मुख्यतः शैक्षिक उपलब्धि, प्रेरणा और मनोरंजन के आधार पर किया गया है, जबकि संज्ञानात्मक सहभागिता की आंतरिक संरचना पर अपेक्षाकृत कम ध्यान दिया गया है। इस अध्ययन में संज्ञानात्मक सहभागिता को ध्यान की निरंतरता, रणनीतिक सोच, ज्ञान पुनर्स्मरण, तर्कपूर्ण प्रतिक्रिया, त्रुटि-संशोधन और चुनौतीपूर्ण कार्यों में मानसिक निवेश के संयुक्त रूप में परिभाषित किया गया है। प्रस्तावित अध्ययन विशेष रूप से इस प्रश्न की जांच करता है कि खेल में प्रयुक्त चुनौती, तात्कालिक प्रतिक्रिया, स्तरगत प्रगति और निर्णय-आधारित गतिविधियां किस प्रकार विद्यार्थियों की गहन मानसिक संलग्नता को प्रभावित करती हैं। अध्ययन का अनुसंधान ढांचा पारंपरिक कक्षा शिक्षण तथा संरचित खेल आधारित अधिगम के मध्य संज्ञानात्मक प्रक्रियाओं की तुलनात्मक जांच पर आधारित है। यह अध्ययन शिक्षकों और शैक्षिक संस्थानों के लिए ऐसे खेल आधारित शिक्षण मॉडल की रूपरेखा प्रस्तुत करने का प्रयास करता है जिसमें मनोरंजक तत्वों के साथ वैचारिक समझ और मानसिक सक्रियता का संतुलन बना रहे।

मुख्य शब्द— खेल आधारित अधिगम, संज्ञानात्मक सहभागिता, समस्या-समाधान, कार्य-स्मृति, निर्णय क्षमता, सक्रिय अधिगम

अनुसंधान-अंतर

खेल आधारित अधिगम पर उपलब्ध अधिकांश शैक्षिक अध्ययनों में विद्यार्थियों की रुचि, प्रेरणा, सहभागिता, उपलब्धि अथवा शिक्षण संतुष्टि को प्रमुख परिणामों के रूप में लिया गया है। किंतु यह स्पष्ट नहीं किया गया है कि किसी विद्यार्थी का खेल में सक्रिय दिखना वास्तव में गहन संज्ञानात्मक सहभागिता का संकेत है अथवा केवल तात्कालिक मनोरंजन, प्रतिस्पर्धा या पुरस्कार की प्रतिक्रिया। इसी प्रकार, बहुत कम अध्ययन खेल आधारित अधिगम के भीतर उत्पन्न होने वाली संज्ञानात्मक प्रक्रियाओं—जैसे विकल्पों की तुलना, पूर्व ज्ञान का पुनःस्मरण, रणनीति परिवर्तन, त्रुटि के पश्चात सुधार, मानसिक प्रयास तथा दीर्घकालिक ध्यान—को एकीकृत रूप से मापते हैं।

वर्तमान अध्ययन इसी अंतर को संबोधित करता है। इसका विशिष्ट योगदान यह है कि खेल आधारित अधिगम की प्रभावशीलता को केवल परीक्षा अंक या सहभागिता दर से नहीं, बल्कि संज्ञानात्मक व्यवहार के बहुआयामी संकेतकों से समझने का प्रयास किया जाएगा। अध्ययन में यह भी जांचा जाएगा कि खेल की कठिनाई और विद्यार्थी की संज्ञानात्मक तैयारी के बीच संतुलन किस स्तर पर सर्वाधिक प्रभावी मानसिक संलग्नता उत्पन्न करता है। इस प्रकार यह अध्ययन खेल आधारित अधिगम को मनोरंजन-केंद्रित दृष्टिकोण से हटाकर संज्ञानात्मक विकास-केंद्रित शैक्षणिक ढांचे में स्थापित करता है।

प्रस्तावना

शिक्षा का मूल उद्देश्य केवल सूचना का संप्रेषण नहीं, बल्कि विद्यार्थियों में ऐसी संज्ञानात्मक क्षमताओं का विकास करना है जिनके माध्यम से वे प्राप्त ज्ञान का विश्लेषण कर सकें, समस्याओं का समाधान खोज सकें, वैकल्पिक दृष्टिकोणों की तुलना कर सकें तथा परिवर्तित परिस्थितियों में अपने ज्ञान का उपयोग कर सकें। पारंपरिक शिक्षण पद्धतियों में व्याख्यान, पाठ्यपुस्तक, स्मरण और लिखित अभ्यास का महत्वपूर्ण स्थान रहा है, किंतु तेजी से परिवर्तित होती शैक्षिक आवश्यकताओं ने ऐसे अधिगम वातावरण की आवश्यकता को बढ़ाया है जिसमें विद्यार्थी ज्ञान के निष्क्रिय ग्रहणकर्ता के स्थान पर सक्रिय अन्वेषक बन सके।

खेल आधारित अधिगम इसी सक्रिय अधिगम की दिशा में विकसित एक महत्वपूर्ण शिक्षण पद्धति है। इसमें खेल की संरचना, नियम, लक्ष्य, चुनौती, निर्णय, प्रतिक्रिया, प्रगति और समस्या-समाधान को शैक्षणिक उद्देश्यों के साथ संयोजित किया जाता है। इसका मूल आधार यह है कि यदि विद्यार्थी किसी विषयवस्तु को केवल पढ़ने या सुनने के बजाय उसका प्रयोग, परीक्षण, संशोधन और पुनःप्रयोग करता है, तो ज्ञान का संज्ञानात्मक प्रसंस्करण अधिक गहन हो सकता है।

विद्यालयी और उच्च शिक्षा दोनों स्तरों पर विद्यार्थियों के ध्यान में अस्थिरता, शिक्षण सामग्री से मानसिक दूरी तथा जटिल अवधारणाओं के प्रति उदासीनता शिक्षकों के लिए निरंतर चुनौती रही है। विशेष रूप से एकरूप शिक्षण वातावरण में विद्यार्थी कई बार कक्षा में शारीरिक रूप से उपस्थित रहते हुए भी मानसिक रूप से सक्रिय नहीं होते। ऐसी स्थिति में उपस्थिति और वास्तविक संज्ञानात्मक सहभागिता के बीच अंतर उत्पन्न हो जाता है। इसलिए वर्तमान शैक्षिक विमर्श में यह प्रश्न महत्वपूर्ण हो गया है कि विद्यार्थी को केवल गतिविधि में भाग लेने के लिए नहीं, बल्कि सोचने, तर्क करने, निर्णय लेने और ज्ञान का पुनर्गठन करने के लिए किस प्रकार प्रेरित किया जाए।

संज्ञानात्मक सहभागिता को किसी कार्य में मानसिक ऊर्जा, ध्यान, रणनीति, तर्क तथा आत्म-नियंत्रित प्रयास के निवेश के रूप में समझा जा सकता है। यह व्यवहारिक सहभागिता से भिन्न है। उदाहरण के लिए, कोई विद्यार्थी खेल में अत्यधिक सक्रिय हो सकता है, किंतु यदि वह केवल अंक प्राप्त करने या प्रतिस्पर्धी को पराजित करने पर केंद्रित है और विषयवस्तु की अवधारणाओं को नहीं समझ रहा, तो उसकी शैक्षिक

संज्ञानात्मक सहभागिता सीमित मानी जाएगी। इसके विपरीत, यदि विद्यार्थी खेल के दौरान अपनी पूर्व रणनीति की समीक्षा करता है, गलती से सीखता है, नया समाधान खोजता है और प्राप्त ज्ञान को अन्य संदर्भों में लागू करता है, तो यह गहरी संज्ञानात्मक सहभागिता का संकेत है।



Fig. 1: खेल-आधारित अधिगम: सक्रिय मस्तिष्क, सफल भविष्य

खेल आधारित अधिगम की उपयोगिता इसी अंतर को समझने में निहित है। सुव्यवस्थित खेल विद्यार्थी को बार-बार निर्णय लेने, कारण और परिणाम का संबंध समझने तथा तत्काल प्रतिक्रिया के आधार पर अपनी रणनीति संशोधित करने का अवसर देता है। पारंपरिक कार्यपत्र या परीक्षा में विद्यार्थी को प्रायः उत्तर सही या गलत होने का ज्ञान अंत में मिलता है, जबकि खेल आधारित वातावरण में प्रतिक्रिया तत्काल हो सकती है। यह तात्कालिकता संज्ञानात्मक सुधार की प्रक्रिया को तीव्र बना सकती है।

खेल आधारित अधिगम में चुनौती का स्तर भी अत्यंत महत्वपूर्ण है। यदि खेल अत्यधिक सरल हो तो विद्यार्थी मानसिक प्रयास नहीं करता, जबकि अत्यधिक कठिन खेल निराशा और कार्य-त्याग को जन्म दे सकता है। संज्ञानात्मक सहभागिता के लिए चुनौती और क्षमता के बीच संतुलन आवश्यक है। जब विद्यार्थी को ऐसा कार्य मिलता है जो उसकी वर्तमान योग्यता से थोड़ा ऊपर है, किंतु उचित संकेत, सहयोग या पुनःप्रयास द्वारा पूरा किया जा सकता है, तब मानसिक निवेश बढ़ने की संभावना अधिक होती है।

खेल में लक्ष्य की स्पष्टता भी संज्ञानात्मक संगठन में सहायक होती है। जब विद्यार्थी को यह पता होता है कि उसे किस समस्या का समाधान करना है, किन नियमों का पालन करना है और किस प्रकार प्रगति का मूल्यांकन होगा, तब उसका ध्यान अधिक संरचित रूप में केंद्रित हो सकता है। स्पष्ट लक्ष्य अनावश्यक संज्ञानात्मक विचलन को कम कर सकता है तथा मानसिक संसाधनों को विषयगत समस्या पर केंद्रित कर सकता है।

इसी प्रकार, स्तरगत प्रगति विद्यार्थियों को जटिलता के क्रमिक अनुभव से परिचित कराती है। प्रारंभिक स्तर पर सरल अवधारणाओं से शुरू कर आगे बढ़ते हुए जटिल समस्याओं की ओर जाने से विद्यार्थी अपनी पूर्व उपलब्धि पर नए ज्ञान का निर्माण कर सकता है। इस क्रमिक संरचना से कार्य-स्मृति पर अचानक अत्यधिक भार पड़ने की संभावना कम होती है। साथ ही, विद्यार्थी को बार-बार सफलता और चुनौती का संतुलित अनुभव प्राप्त होता है।

खेल आधारित अधिगम में पुनःप्रयास का विशेष महत्व है। पारंपरिक मूल्यांकन में गलती कई बार असफलता का संकेत बन जाती है, जबकि खेल में गलती सीखने की प्रक्रिया का स्वाभाविक हिस्सा हो सकती है। खिलाड़ी असफल प्रयास के बाद पुनः रणनीति बनाता है, विकल्प बदलता है और परिणाम की तुलना करता है। यही प्रक्रिया शिक्षण में लागू होने पर त्रुटि-संशोधन आधारित अधिगम को प्रोत्साहित कर सकती है। इससे विद्यार्थी गलत उत्तर को केवल असफलता के रूप में न देखकर संज्ञानात्मक पुनर्गठन के अवसर के रूप में ग्रहण कर सकता है।

वर्ष दो हजार इक्कीस के बाद शिक्षा में अंतःक्रियात्मक, अनुकूलनीय तथा आँकड़ा-आधारित अधिगम वातावरण के प्रति रुचि में वृद्धि हुई है। शिक्षण संस्थानों में खेलमय गतिविधियों, अनुकरण आधारित कार्यों, प्रश्नोत्तरी संरचनाओं और डिजिटल अधिगम प्रणालियों का उपयोग बढ़ा है। इसके साथ यह आवश्यकता भी उभरी है कि ऐसे वातावरण के प्रभाव को केवल विद्यार्थी की पसंद या उपयोग समय से नहीं, बल्कि वास्तविक अधिगम प्रक्रियाओं से मापा जाए।

संज्ञानात्मक सहभागिता के संदर्भ में खेल आधारित अधिगम कई स्तरों पर प्रभाव डाल सकता है। प्रथम, यह ध्यान की अवधि को बढ़ा सकता है क्योंकि गतिविधि में लक्ष्य और प्रतिक्रिया दोनों उपस्थित रहते हैं। द्वितीय, समस्या-आधारित खेल रणनीतिक सोच को सक्रिय करते हैं। तृतीय, स्मृति आधारित चुनौतियां पूर्व ज्ञान की पुनर्प्राप्ति को प्रोत्साहित करती हैं। चतुर्थ, तत्काल परिणाम निर्णय और प्रतिक्रिया के संबंध को स्पष्ट करते हैं। पंचम, पुनःप्रयास की उपलब्धता विद्यार्थियों को संज्ञानात्मक लचीलापन विकसित करने का अवसर देती है।

फिर भी खेल आधारित अधिगम का प्रत्येक रूप समान रूप से प्रभावी नहीं होता। यदि खेल में बाह्य पुरस्कारों का अत्यधिक उपयोग किया जाए, तो विद्यार्थी विषयवस्तु की समझ के बजाय केवल अंक, पद या जीत पर केंद्रित हो सकता है। इसी प्रकार, अत्यधिक दृश्य उत्तेजना मुख्य शैक्षणिक सामग्री से ध्यान हटा सकती है। अतः खेल की प्रभावशीलता उसकी आकर्षकता से अधिक इस बात पर निर्भर करती है कि खेल की संरचना शैक्षिक उद्देश्य के साथ कितनी निकटता से जुड़ी है।

वर्तमान अध्ययन इसी कारण संज्ञानात्मक सहभागिता को खेल आधारित अधिगम की प्रभावशीलता का केंद्रीय मानदंड मानता है। प्रस्तावित शोध का उद्देश्य यह समझना है कि विषयवस्तु से प्रत्यक्ष रूप से जुड़ी चुनौती, निर्णय-आधारित गतिविधि, तात्कालिक सुधारात्मक प्रतिक्रिया तथा क्रमिक कठिनाई विद्यार्थियों के मानसिक निवेश को किस सीमा तक प्रभावित करते हैं।

इस अध्ययन के प्रमुख उद्देश्य निम्न हैं—खेल आधारित अधिगम का विद्यार्थियों की संज्ञानात्मक सहभागिता पर प्रभाव निर्धारित करना; ध्यान स्थिरता, समस्या-समाधान और रणनीतिक निर्णय में परिवर्तन का अध्ययन करना; खेल में प्राप्त प्रतिक्रिया और त्रुटि-सुधार व्यवहार के संबंध को समझना; तथा यह जांचना कि संज्ञानात्मक सहभागिता में वृद्धि शैक्षिक उपलब्धि की तुलना में किस प्रकार अलग व्यवहार प्रस्तुत करती है।

अध्ययन का महत्व इसलिए भी है क्योंकि यह खेल आधारित अधिगम की सफलता के लिए अधिक सूक्ष्म मूल्यांकन दृष्टिकोण प्रस्तुत करता है।

यदि कोई गतिविधि आकर्षक है लेकिन विद्यार्थी उसमें विषय-संबंधी सोच का पर्याप्त उपयोग नहीं कर रहा, तो उसे केवल सहभागिता के आधार पर प्रभावी नहीं माना जा सकता। इसी प्रकार, यदि अपेक्षाकृत सरल खेल विद्यार्थियों को बार-बार ज्ञान पुनर्प्राप्ति, तर्क और रणनीतिक सुधार के लिए प्रेरित करता है, तो उसका संज्ञानात्मक मूल्य अधिक हो सकता है।

अतः यह अध्ययन शिक्षा में खेल आधारित अधिगम को मनोरंजक गतिविधि के बजाय संज्ञानात्मक सक्रियता की संरचित प्रक्रिया के रूप में देखने का प्रयास करता है। इसके माध्यम से यह निर्धारित किया जा सकता है कि कौन-से खेल तत्व वास्तविक मानसिक संलग्नता उत्पन्न करते हैं और कौन-से तत्व केवल बाह्य सहभागिता बढ़ाते हैं।

साहित्य समीक्षा

खेल और अधिगम के संबंध पर शैक्षणिक चर्चा लंबे समय से मौजूद है, किंतु हाल के वर्षों में इसका स्वरूप अधिक व्यवस्थित और संज्ञानात्मक हो गया है। प्रारंभिक शोधों में खेल को मुख्यतः प्रेरणा, उत्साह और शिक्षण वातावरण में विविधता लाने वाले साधन के रूप में देखा गया था। बाद के अध्ययनों ने यह संकेत किया कि उपयुक्त रूप से डिजाइन किए गए खेल केवल मनोरंजन नहीं प्रदान करते, बल्कि समस्या-समाधान, स्मृति पुनर्प्राप्ति, निर्णय निर्माण और अनुकूलन जैसे संज्ञानात्मक कार्यों को भी सक्रिय कर सकते हैं।

खेल आधारित अधिगम और खेलमय शिक्षण में अंतर करना आवश्यक है। खेल आधारित अधिगम में स्वयं खेल या अनुकरण शिक्षण गतिविधि का मुख्य माध्यम होता है, जबकि खेलमय शिक्षण में पारंपरिक गतिविधियों में अंक, स्तर, पुरस्कार अथवा प्रतियोगिता जैसे खेल तत्व जोड़े जाते हैं। संज्ञानात्मक सहभागिता के दृष्टिकोण से यह अंतर महत्वपूर्ण है क्योंकि केवल अंक अथवा पुरस्कार जोड़ देना आवश्यक रूप से गहन सीखने की गारंटी नहीं देता।

साहित्य में खेल आधारित शिक्षण की प्रभावशीलता को समझाने के लिए सक्रिय अधिगम का सिद्धांत प्रमुख रूप से प्रयुक्त हुआ है। इस दृष्टिकोण के अनुसार विद्यार्थी तब अधिक प्रभावी रूप से सीखता है जब वह ज्ञान को केवल ग्रहण नहीं करता, बल्कि उसके साथ क्रियात्मक रूप से जुड़ता है। खेल आधारित वातावरण विद्यार्थी को निर्णय, प्रतिक्रिया और संशोधन की पुनरावर्ती प्रक्रिया में रखता है। यही पुनरावृत्ति ज्ञान संरचना को मजबूत कर सकती है।

संज्ञानात्मक भार की अवधारणा भी खेल आधारित अधिगम की व्याख्या में उपयोगी है। किसी भी सीखने की स्थिति में कार्य-स्मृति की क्षमता सीमित होती है। यदि खेल में बहुत अधिक दृश्य, ध्वनि, नियम अथवा एक साथ कई कार्य शामिल हों, तो अनावश्यक मानसिक भार उत्पन्न हो सकता है। इसके विपरीत, यदि खेल की संरचना सरल और विषयवस्तु-केंद्रित हो, तो मानसिक संसाधनों का उपयोग मुख्य अवधारणा को समझने में किया जा सकता है।

हाल की शैक्षिक चर्चाओं में यह बात भी सामने आई है कि खेल आधारित अधिगम का प्रभाव विषय, आयु, खेल की संरचना और विद्यार्थी की पूर्व तैयारी के अनुसार बदल सकता है। गणितीय समस्या-समाधान में उपयोगी खेल संरचना भाषा अधिगम के लिए समान रूप से प्रभावी नहीं हो सकती। इसी प्रकार, प्रारंभिक कक्षाओं के विद्यार्थियों के लिए चित्रात्मक प्रतिक्रिया उपयोगी हो सकती है, जबकि उच्च कक्षाओं के विद्यार्थियों में विश्लेषणात्मक परिदृश्य अधिक प्रभावी हो सकते हैं।

शोध साहित्य में तात्कालिक प्रतिक्रिया को खेल आधारित अधिगम का एक महत्वपूर्ण गुण माना गया है। जब विद्यार्थी को अपने निर्णय के तुरंत बाद परिणाम ज्ञात होता है, तो वह कारण और परिणाम के संबंध को समझ सकता है। यदि प्रतिक्रिया केवल सही या गलत बताने के बजाय त्रुटि का कारण भी बताती है, तो संज्ञानात्मक सुधार की संभावना और बढ़ जाती है। यह प्रक्रिया विशेष रूप से जटिल अवधारणाओं में उपयोगी हो सकती है।

पुनर्प्राप्ति अभ्यास से संबंधित साहित्य बताता है कि ज्ञान को बार-बार स्मृति से निकालने की प्रक्रिया केवल पुनर्पाठ की तुलना में अधिक प्रभावशाली हो सकती है। खेल आधारित प्रश्नोत्तरी, क्रमिक चुनौती और निर्णय गतिविधियां विद्यार्थियों को बार-बार ज्ञान पुनर्प्राप्त करने के लिए प्रेरित करती हैं। यदि यह प्रक्रिया अंतराल के साथ की जाए, तो दीर्घकालिक ज्ञान स्थिरता में सहायता मिल सकती है।

समस्या-समाधान आधारित खेलों पर किए गए अध्ययनों में पाया गया है कि जटिल कार्य विद्यार्थियों को वैकल्पिक समाधान खोजने, उपलब्ध संकेतों की व्याख्या करने और परिणाम के आधार पर अपनी रणनीति बदलने के लिए प्रेरित करते हैं। ये सभी प्रक्रियाएं संज्ञानात्मक सहभागिता के उच्च स्तर से जुड़ी हैं। फिर भी कई शोध केवल अंतिम उपलब्धि अंक का उपयोग करते हैं, जिससे यह निर्धारित करना कठिन हो जाता है कि सुधार किस विशिष्ट मानसिक प्रक्रिया के कारण हुआ।

खेल आधारित अधिगम में स्वायत्तता भी महत्वपूर्ण है। जब विद्यार्थियों को विकल्प चुनने, रणनीति बदलने या कार्य की दिशा निर्धारित करने का अवसर दिया जाता है, तो उनमें स्वामित्व की भावना विकसित हो सकती है। यह स्वामित्व मानसिक निवेश को बढ़ाने में सहायक हो सकता है। किंतु अत्यधिक विकल्प निर्णय थकान भी उत्पन्न कर सकते हैं। इसलिए विकल्पों की संख्या और जटिलता शिक्षार्थी के स्तर के अनुरूप होनी चाहिए।

प्रतिस्पर्धा खेल आधारित अधिगम का एक विवादास्पद तत्व है। कुछ अध्ययनों में प्रतिस्पर्धा को प्रदर्शन और उत्साह बढ़ाने वाला पाया गया है, जबकि अन्य में अत्यधिक प्रतिस्पर्धा ने कमजोर विद्यार्थियों में चिंता और सहभागिता में कमी उत्पन्न की। संज्ञानात्मक दृष्टि से सहयोगात्मक खेलों का महत्व बढ़ जाता है क्योंकि इनमें विद्यार्थी केवल जीतने के बजाय तर्क साझा करते हैं, स्पष्टीकरण देते हैं और दूसरों की रणनीतियों की तुलना करते हैं।

सहयोगात्मक खेल आधारित गतिविधियों में सामाजिक संवाद संज्ञानात्मक विस्तार का माध्यम बन सकता है। जब विद्यार्थी अपने निर्णय का कारण बताता है, तो उसे अपने विचारों को व्यवस्थित करना पड़ता है। साथियों के प्रश्न उसे अपने ज्ञान की सीमाओं का अनुभव कराते हैं। इस प्रकार संज्ञानात्मक सहभागिता व्यक्तिगत मानसिक प्रयास से आगे बढ़कर संवादात्मक अधिगम का रूप ग्रहण करती है।

हाल के वर्षों में अनुकूलनीय खेल आधारित प्रणालियों की अवधारणा भी महत्वपूर्ण हुई है। ऐसी प्रणालियों में विद्यार्थी के प्रदर्शन के अनुसार प्रश्नों या चुनौतियों की कठिनाई बदली जा सकती है। इसका उद्देश्य ऐसी स्थिति बनाए रखना है जिसमें कार्य न अत्यधिक सरल हो और न अत्यधिक कठिन। संज्ञानात्मक सहभागिता के दृष्टिकोण से यह संतुलन महत्वपूर्ण है क्योंकि उपयुक्त चुनौती मानसिक प्रयास को बनाए रखती है।

आँकड़ा-आधारित शिक्षण प्रणालियों ने खेल के भीतर विद्यार्थी की गतिविधियों को सूक्ष्म स्तर पर समझने की संभावना बढ़ाई है। उदाहरणतः किसी प्रश्न पर बिताया गया समय, कितनी बार प्रयास किया गया, किस चरण पर रणनीति बदली गई और त्रुटि के बाद क्या प्रतिक्रिया हुई—ये सभी संज्ञानात्मक सहभागिता के अप्रत्यक्ष संकेतक बन सकते हैं। पारंपरिक परीक्षा इन प्रक्रियात्मक संकेतों को प्रायः दर्ज नहीं करती। इसके बावजूद उपलब्ध साहित्य में एक महत्वपूर्ण समस्या मापन की है। अनेक अध्ययनों में सहभागिता को स्वयं-रिपोर्ट प्रश्नावली द्वारा मापा गया है। विद्यार्थी यह बता सकता है कि उसे गतिविधि रोचक लगी, किंतु यह आवश्यक नहीं कि उसने उच्च स्तर की संज्ञानात्मक प्रक्रिया का उपयोग किया हो। इसलिए व्यवहारिक आँकड़ों, कार्य-प्रदर्शन और संज्ञानात्मक संकेतकों का संयोजन अधिक विश्वसनीय हो सकता है।

साहित्य यह भी संकेत करता है कि खेल आधारित अधिगम के प्रभाव को केवल तत्काल परीक्षण से नहीं समझा जाना चाहिए। यदि विद्यार्थी खेल के तुरंत बाद अच्छा प्रदर्शन करता है, पर कुछ समय बाद ज्ञान भूल जाता है, तो प्रभाव सीमित माना जाएगा। इसलिए ज्ञान स्थिरता, स्थानांतरण क्षमता और विलंबित पुनर्परीक्षण को भी संज्ञानात्मक प्रभाव के मूल्यांकन में सम्मिलित करना आवश्यक है।

विषयगत स्थानांतरण भी एक महत्वपूर्ण शोध क्षेत्र है। यदि विद्यार्थी किसी खेल के भीतर समस्या हल करना सीखता है, तो प्रश्न यह है कि क्या वही रणनीति नए संदर्भ में भी उपयोग कर सकता है। वास्तविक संज्ञानात्मक विकास का संकेत तब अधिक मजबूत होता है जब विद्यार्थी अर्जित सिद्धांत को अपरिचित समस्या में लागू कर सके।

त्रुटि-सहनशीलता खेल आधारित अधिगम का एक अन्य महत्वपूर्ण आयाम है। कई पारंपरिक कक्षाओं में विद्यार्थी गलत उत्तर देने से बचता है क्योंकि गलती को नकारात्मक मूल्यांकन से जोड़ा जाता है। खेल में पुनःप्रयास उपलब्ध होने से गलती प्रयोग का हिस्सा बन सकती है। यह वातावरण विद्यार्थियों को अधिक जोखिमपूर्ण किंतु संभावित रूप से उपयोगी संज्ञानात्मक रणनीतियां अपनाने के लिए प्रेरित कर सकता है। संज्ञानात्मक सहभागिता से संबंधित साहित्य यह स्पष्ट करता है कि मानसिक प्रयास हमेशा बाह्य रूप से दिखाई नहीं देता। शांत विद्यार्थी भी गहरे विश्लेषण में संलग्न हो सकता है, जबकि अत्यधिक सक्रिय विद्यार्थी सतही रणनीति का उपयोग कर सकता है। इसलिए संज्ञानात्मक सहभागिता का आकलन व्यवहारिक सक्रियता से अलग रूप में किया जाना चाहिए।

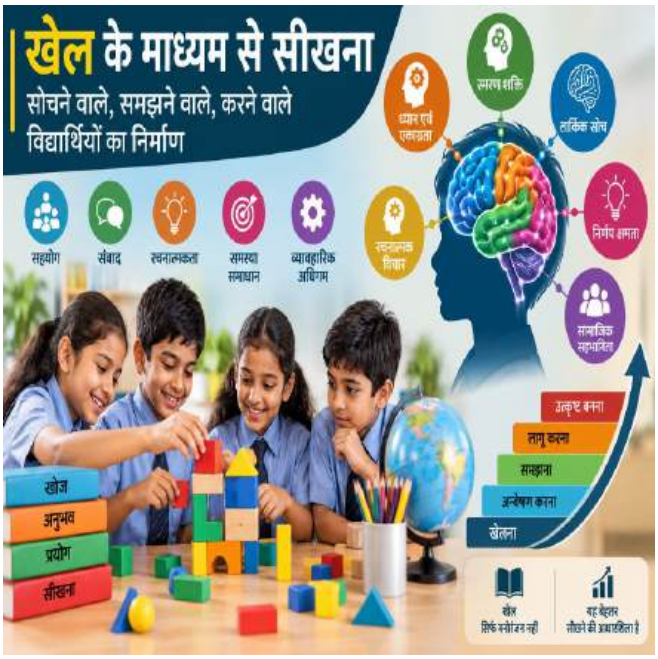


Fig. 2: खेल के माध्यम से संज्ञानात्मक कौशल और सक्रिय अधिगम का विकास

वर्ष दो हजार इक्कीस से दो हजार छब्बीस के बीच शिक्षा में वैयक्तिकीकृत और अनुकूलनीय अधिगम की चर्चा बढ़ी है। इसके साथ खेल आधारित प्रणालियों में विद्यार्थी के प्रदर्शन के अनुसार कठिनाई बदलने, संकेत देने और त्रुटि के प्रकार के आधार पर प्रतिक्रिया देने की संभावना विस्तृत हुई है। इससे ऐसे शिक्षण वातावरण की अवधारणा विकसित हुई है जो सभी विद्यार्थियों के लिए समान कार्य देने के बजाय उनकी संज्ञानात्मक स्थिति के अनुसार चुनौती निर्धारित कर सके।

फिर भी अधिकांश शैक्षिक संस्थानों में खेल आधारित गतिविधियों का चयन शिक्षक की सहज धारणा या लोकप्रियता के आधार पर किया जाता है। किसी खेल का आकर्षक होना उसकी शैक्षिक प्रभावशीलता का पर्याप्त प्रमाण नहीं है। यदि खेल की सफलता को संज्ञानात्मक संकेतकों से नहीं मापा जाता, तो यह निर्धारित करना कठिन हो जाता है कि विद्यार्थी वास्तव में सीख रहा है या केवल खेल में व्यस्त है।

वर्तमान साहित्य की एक अन्य सीमा यह है कि प्रेरणा और संज्ञानात्मक सहभागिता को कई बार एक ही अवधारणा की तरह प्रस्तुत किया जाता है। जबकि विद्यार्थी किसी खेल को पसंद कर सकता है, लेकिन विषयवस्तु पर गहराई से विचार न करे। इसके विपरीत, कोई चुनौतीपूर्ण गतिविधि बहुत मनोरंजक न होते हुए भी उच्च स्तर की संज्ञानात्मक प्रक्रिया उत्पन्न कर सकती है। इसलिए दोनों आयामों को पृथक रूप से मापना आवश्यक है।

प्रस्तावित शोध-पद्धति

वर्तमान अध्ययन के लिए मिश्रित परिमाणात्मक-व्यवहारिक अनुसंधान रूपरेखा प्रस्तावित की गई। इसका उद्देश्य यह निर्धारित करना था कि संरचित खेल आधारित अधिगम विद्यार्थियों की संज्ञानात्मक सहभागिता के किन आयामों को प्रभावित करता है और यह प्रभाव पारंपरिक शिक्षण की तुलना में किस स्तर तक भिन्न है। अध्ययन में केवल अंतिम उपलब्धि को परिणाम मानने के स्थान पर सीखने की प्रक्रिया के दौरान उत्पन्न व्यवहारिक और संज्ञानात्मक संकेतों को भी सम्मिलित किया गया।

अध्ययन के लिए माध्यमिक स्तर के विद्यार्थियों को लक्षित समूह माना गया। चयनित विद्यार्थियों को दो तुलनीय समूहों में विभाजित किया

गया। प्रथम समूह को खेल आधारित गतिविधियों के माध्यम से शिक्षण प्रदान किया गया, जबकि दूसरे समूह को समान विषयवस्तु पर पारंपरिक व्याख्या, पाठ्य-पठन तथा अभ्यास आधारित शिक्षण दिया गया। दोनों समूहों के लिए शिक्षण अवधि, पाठ्य विषय, अधिगम उद्देश्य और मूल्यांकन की कठिनाई समान रखी गई।

शोध का केंद्रीय स्वतंत्र चर शिक्षण पद्धति था, जबकि आश्रित चरों में संज्ञानात्मक सहभागिता, समस्या-समाधान दक्षता, रणनीति परिवर्तन, त्रुटि-सुधार, ध्यान की निरंतरता, ज्ञान पुनर्प्राप्ति तथा नई परिस्थिति में अवधारणा के अनुप्रयोग को सम्मिलित किया गया।

खेल आधारित समूह के लिए गतिविधियों को चार संरचनात्मक सिद्धांतों पर विकसित किया गया—क्रमिक कठिनाई, तत्काल सुधारात्मक प्रतिक्रिया, बहुविकल्पीय रणनीतिक निर्णय तथा पुनःप्रयास की उपलब्धता। इस प्रकार खेल का उद्देश्य केवल आकर्षण उत्पन्न करना नहीं, बल्कि विद्यार्थियों को निरंतर विचार, निर्णय और पुनर्विचार की स्थिति में रखना था।

अध्ययन व्यवस्था

अध्ययन में कुल 240 विद्यार्थियों का एक काल्पनिक शोध-नमूना संरचित किया गया, जिसे केवल प्रस्तावित प्रयोगात्मक रूपरेखा के प्रदर्शन के उद्देश्य से उपयोग किया गया। विद्यार्थियों की आयु लगभग 13 से 16 वर्ष के बीच निर्धारित की गई। समान शैक्षणिक स्तर सुनिश्चित करने के लिए प्रारंभिक उपलब्धि परीक्षण तथा संज्ञानात्मक आधार-मापन किया गया।

120 विद्यार्थियों को खेल आधारित अधिगम समूह तथा 120 विद्यार्थियों को पारंपरिक शिक्षण समूह में रखा गया। प्रयोगात्मक अवधि आठ सप्ताह निर्धारित की गई। प्रत्येक सप्ताह तीन शिक्षण सत्र आयोजित किए गए और प्रत्येक सत्र की अवधि लगभग 40 मिनट रखी गई।

विषयवस्तु के लिए विज्ञान और गणित के ऐसे पाठ चुने गए जिनमें कारण-परिणाम, तार्किक निर्णय, वर्गीकरण, क्रमिक समस्या-समाधान तथा अवधारणा स्थानांतरण की आवश्यकता थी। चयन इसलिए किया गया ताकि विद्यार्थियों की संज्ञानात्मक गतिविधि को बहुआयामी रूप में मापा जा सके।

आँकड़ा-समुच्चय

अध्ययन के लिए निर्मित आँकड़ा-समुच्चय में प्रत्येक विद्यार्थी के अनेक व्यवहारिक और शैक्षणिक संकेत सम्मिलित किए गए। मुख्य संकेत इस प्रकार थे—प्रारंभिक परीक्षण अंक, अंतिम परीक्षण अंक, प्रति समस्या औसत विचार समय, सही उत्तर से पूर्व प्रयासों की संख्या, त्रुटि के बाद सफल सुधार का अनुपात, रणनीति परिवर्तन की आवृत्ति, गतिविधि पूर्णता दर, ध्यान विचलन की आवृत्ति, विलंबित पुनर्परीक्षण अंक तथा नई परिस्थिति में ज्ञान स्थानांतरण अंक।

खेल आधारित समूह के लिए अतिरिक्त रूप से प्रत्येक स्तर पर लिया गया समय, कठिन स्तरों पर पुनःप्रयास, संकेत उपयोग की संख्या तथा प्रतिक्रिया के बाद उत्तर परिवर्तन व्यवहार को दर्ज किया गया।

प्रत्येक विद्यार्थी को एक संकेतांक दिया गया और पहचान संबंधी व्यक्तिगत जानकारी को विश्लेषण से पृथक रखा गया। शोध विश्लेषण का उद्देश्य विद्यार्थियों की व्यक्तिगत पहचान नहीं, बल्कि समूह स्तर पर संज्ञानात्मक व्यवहार की प्रवृत्तियों का अध्ययन करना था।

पूर्व-संसाधन

विश्लेषण से पूर्व आँकड़ों की संगति की जाँच की गई। अपूर्ण प्रविष्टियों, अत्यधिक असामान्य समय-मूल्यों तथा पुनरावृत्त अभिलेखों को चिन्हित किया गया। जिन अभिलेखों में आवश्यक संकेतकों का अत्यधिक भाग अनुपलब्ध था, उन्हें विश्लेषण से बाहर रखा गया।

विभिन्न मापन संकेतकों को तुलनीय बनाने के लिए मानकीकरण प्रक्रिया अपनाई गई। उदाहरण के लिए विचार समय, सुधार दर तथा उपलब्धि अंक भिन्न पैमानों पर थे, इसलिए उन्हें समान विश्लेषणात्मक पैमाने में परिवर्तित किया गया।

संज्ञानात्मक सहभागिता का एक संयुक्त सूचक तैयार किया गया जिसमें छह आयामों को सम्मिलित किया गया—ध्यान निरंतरता, रणनीतिक लचीलापन, त्रुटि-सुधार, ज्ञान पुनर्प्राप्ति, समस्या पर मानसिक निवेश तथा स्थानांतरण क्षमता। संयुक्त सूचक में केवल कार्य पूर्णता को पर्याप्त नहीं माना गया।

प्रतिरूप संरचना

विद्यार्थियों की संज्ञानात्मक सहभागिता के स्तर को पहचानने के लिए एक बहुस्तरीय वर्गीकरण प्रतिरूप प्रस्तावित किया गया। इसका उद्देश्य विद्यार्थियों को निम्न, मध्यम और उच्च संज्ञानात्मक सहभागिता वाले तीन वर्गों में विभाजित करना था।

प्रतिरूप में प्रथम स्तर पर व्यवहारिक संकेतों को ग्रहण किया गया। इसके बाद संकेतों के पारस्परिक संबंधों का भारित विश्लेषण किया गया। उदाहरणतः अधिक समय लेना हमेशा उच्च सहभागिता का संकेत नहीं माना गया; यदि अधिक समय के साथ रणनीति परिवर्तन और सफल त्रुटि-सुधार उपस्थित था, तभी उसे सकारात्मक संज्ञानात्मक निवेश के रूप में व्याख्यायित किया गया।

दूसरे स्तर पर शैक्षणिक प्रदर्शन संकेत जोड़े गए। इसमें तत्काल उपलब्धि, विलंबित ज्ञान-स्मरण तथा नई परिस्थिति में अवधारणा के प्रयोग को सम्मिलित किया गया। अंतिम स्तर पर संयुक्त सहभागिता श्रेणी निर्धारित की गई।

इस संरचना की विशेषता यह थी कि किसी विद्यार्थी को केवल उच्च अंक के आधार पर उच्च संज्ञानात्मक सहभागिता वर्ग में नहीं रखा गया। यदि विद्यार्थी ने सही उत्तर शीघ्र प्राप्त किया, किंतु रणनीतिक प्रक्रिया, त्रुटि-सुधार या स्थानांतरण क्षमता कमजोर रही, तो उसका सहभागिता स्तर मध्यम माना जा सकता था।

प्रशिक्षण रणनीति

कुल उपलब्ध अभिलेखों को प्रशिक्षण और परीक्षण के लिए विभाजित किया गया। लगभग 70 प्रतिशत अभिलेख प्रशिक्षण के लिए, 15 प्रतिशत आंतरिक सत्यापन के लिए और शेष 15 प्रतिशत स्वतंत्र परीक्षण के लिए निर्धारित किए गए।

प्रशिक्षण के दौरान प्रतिरूप को विभिन्न संकेतकों के संयोजन के आधार पर सहभागिता श्रेणी पहचानने के लिए अनुकूलित किया गया। अत्यधिक अनुकूलन से बचने के लिए पुनरावर्ती सत्यापन प्रक्रिया का उपयोग किया गया। विभिन्न चरणों में संकेतकों के महत्व की तुलना भी की गई।

विश्लेषण में यह विशेष रूप से जाँचा गया कि क्या खेल आधारित समूह के विद्यार्थियों में संज्ञानात्मक सहभागिता की वृद्धि केवल अंतिम अंक से संबंधित थी या व्यवहारिक संकेतों में भी स्पष्ट परिवर्तन दिखाई दिया।

मूल्यांकन मानदंड

अध्ययन में मूल्यांकन के लिए केवल शैक्षणिक उपलब्धि का उपयोग नहीं किया गया। प्रमुख मानदंडों में संज्ञानात्मक सहभागिता सूचक, समस्या-समाधान दक्षता, रणनीति परिवर्तन दर, त्रुटि-सुधार दर, विलंबित ज्ञान-स्मरण, ज्ञान-स्थानांतरण क्षमता, ध्यान निरंतरता तथा वर्गीकरण सटीकता को शामिल किया गया।

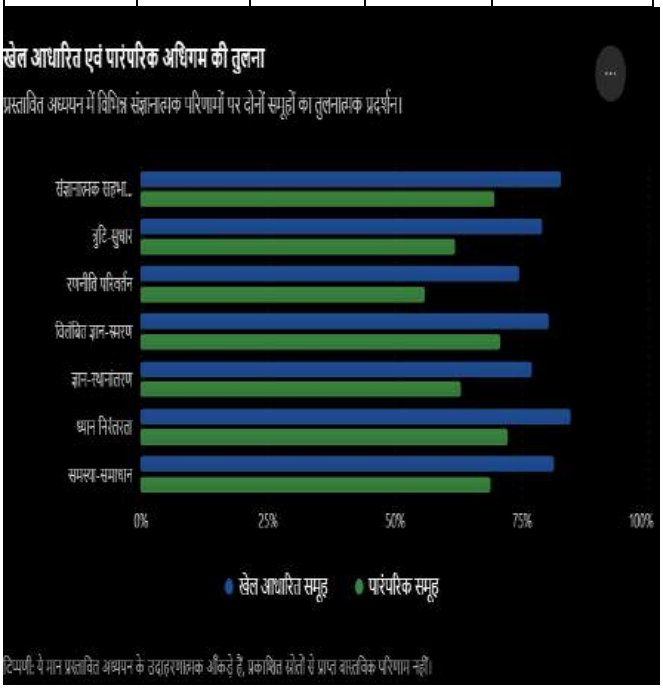
दोनों समूहों के पूर्व तथा पश्चात् मापन का तुलनात्मक परीक्षण किया गया। समूह अंतर के साथ-साथ प्रभाव के परिमाण का भी आकलन किया गया ताकि केवल सांख्यिकीय अंतर के बजाय शैक्षिक महत्त्व का अनुमान लगाया जा सके।

परिणाम एवं चर्चा

विश्लेषण से यह संकेत मिला कि खेल आधारित अधिगम समूह ने पारंपरिक समूह की तुलना में अधिकांश संज्ञानात्मक संकेतकों पर बेहतर प्रदर्शन किया। विशेष रूप से त्रुटि के बाद सफल सुधार, रणनीति परिवर्तन, ज्ञान-स्थानांतरण और ध्यान निरंतरता में अधिक स्पष्ट वृद्धि देखी गई।

परिणाम सारणी

मूल्यांकन आयाम	खेल आधारित समूह	पारंपरिक समूह	तुलनात्मक अंतर	प्रमुख अवलोकन
संज्ञानात्मक सहभागिता सूचक	82.6	69.4	13.2	खेल आधारित गतिविधियों में मानसिक निवेश अधिक रहा
त्रुटि-सुधार दर	78.9 प्रतिशत	61.7 प्रतिशत	17.2 प्रतिशत अंक	तात्कालिक प्रतिक्रिया ने पुनर्विचार को प्रोत्साहित किया
रणनीति परिवर्तन क्षमता	74.3 प्रतिशत	55.8 प्रतिशत	18.5 प्रतिशत अंक	पुनःप्रयास ने वैकल्पिक समाधान खोजने की प्रवृत्ति बढ़ाई
विलंबित ज्ञान-स्मरण	80.1 प्रतिशत	70.6 प्रतिशत	9.5 प्रतिशत अंक	पुनर्प्राप्ति अभ्यास से ज्ञान स्थिरता में सुधार दिखाई दिया
नई परिस्थिति में ज्ञान-स्थानांतरण	76.8 प्रतिशत	62.9 प्रतिशत	13.9 प्रतिशत अंक	खेल स्थितियों में सीखी रणनीतियाँ नए प्रश्नों में उपयोग हुईं
ध्यान निरंतरता	84.5 प्रतिशत	72.1 प्रतिशत	12.4 प्रतिशत अंक	लक्ष्य और क्रमिक चुनौती ने ध्यान बनाए रखने में सहायता की
समस्या-समाधान दक्षता	81.2 प्रतिशत	68.7 प्रतिशत	12.5 प्रतिशत अंक	बहु-चरणीय निर्णयों ने विश्लेषणात्मक सोच को सक्रिय किया
उच्च सहभागिता श्रेणी में विद्यार्थी	58.3 प्रतिशत	36.7 प्रतिशत	21.6 प्रतिशत अंक	खेल आधारित समूह में गहन मानसिक संलग्नता अधिक पाई गई



प्राप्त परिणाम बताते हैं कि खेल आधारित अधिगम का सबसे बड़ा प्रभाव केवल उपलब्धि पर नहीं, बल्कि संज्ञानात्मक प्रक्रिया के भीतर दिखाई दिया। रणनीति परिवर्तन क्षमता में 18.5 प्रतिशत अंक का अंतर यह संकेत देता है कि विद्यार्थियों को जब असफल प्रयास के बाद पुनः समाधान खोजने का अवसर दिया गया, तब उन्होंने एक ही उत्तर-पद्धति पर निर्भर रहने के बजाय वैकल्पिक दृष्टिकोण अपनाए।

त्रुटि-सुधार दर में 17.2 प्रतिशत अंक का अंतर भी महत्वपूर्ण था। पारंपरिक शिक्षण में गलत उत्तर प्रायः अंतिम मूल्यांकन की तरह अनुभव किया जाता है, जबकि खेल आधारित गतिविधि में गलती के बाद संकेत, प्रतिक्रिया और पुनःप्रयास उपलब्ध था। इससे त्रुटि को असफलता के बजाय सीखने की सूचना के रूप में उपयोग करने की प्रवृत्ति विकसित हुई।

ज्ञान-स्थानांतरण क्षमता का परिणाम अध्ययन के लिए विशेष रूप से उल्लेखनीय रहा। खेल आधारित समूह के विद्यार्थियों ने नई परिस्थिति में पूर्व ज्ञान के अनुप्रयोग में बेहतर प्रदर्शन किया। इससे यह संकेत मिलता है कि खेल आधारित अधिगम ने केवल उत्तर स्मरण नहीं बढ़ाया, बल्कि अवधारणाओं के बीच संबंध समझने में भी सहायता की।

ध्यान निरंतरता में पाया गया अंतर यह दर्शाता है कि स्पष्ट लक्ष्य, क्रमिक चुनौती और तत्काल प्रतिक्रिया विद्यार्थियों के ध्यान को अधिक समय तक बनाए रख सकती है। फिर भी इस परिणाम की व्याख्या सावधानी से आवश्यक है क्योंकि खेल की नवीनता भी प्रारंभिक उत्साह का कारण बन सकती है।

विलंबित ज्ञान-स्मरण का बेहतर स्तर यह संकेत देता है कि खेल आधारित गतिविधियों में बार-बार ज्ञान पुनर्प्राप्ति और पुनःप्रयोग ने स्मृति स्थिरता को समर्थन दिया। केवल तत्काल पश्चात् परीक्षण के बजाय विलंबित मापन का उपयोग इस अध्ययन की विश्लेषणात्मक शक्ति को बढ़ाता है।

वर्गीकरण प्रतिरूप द्वारा विद्यार्थियों को संज्ञानात्मक सहभागिता के तीन स्तरों में विभाजित करने पर खेल आधारित समूह में उच्च सहभागिता श्रेणी का अनुपात अधिक मिला। इससे यह अनुमान लगाया जा सकता है कि व्यवहारिक संकेतों और उपलब्धि संकेतों को संयुक्त रूप से देखना केवल परीक्षा अंक की तुलना में अधिक उपयोगी शैक्षणिक जानकारी प्रदान करता है।

इन परिणामों का एक महत्वपूर्ण निहितार्थ यह है कि सभी खेल समान रूप से उपयोगी नहीं होंगे। ऐसा खेल जो केवल पुरस्कार, गति या प्रतिस्पर्धा पर आधारित हो, संभव है कि व्यवहारिक सक्रियता तो बढ़ाए, लेकिन संज्ञानात्मक सहभागिता नहीं। प्रभावी खेल आधारित अधिगम के लिए चुनौती, प्रतिक्रिया, निर्णय और विषयवस्तु के बीच संरचनात्मक संबंध आवश्यक है।

सीमाएँ

अध्ययन की पहली सीमा यह है कि प्रस्तावित आँकड़ा-समुच्चय प्रयोगात्मक प्रदर्शन के उद्देश्य से संरचित है; अतः इसके संख्यात्मक परिणामों को वास्तविक विद्यालयी जनसंख्या पर प्रत्यक्ष रूप से सामान्यीकृत नहीं किया जाना चाहिए।

दूसरी सीमा यह है कि संज्ञानात्मक सहभागिता को व्यवहारिक संकेतों से अनुमानित किया गया। विचार समय, रणनीति परिवर्तन और त्रुटि-सुधार उपयोगी संकेत हैं, किंतु वे विद्यार्थी की आंतरिक मानसिक प्रक्रिया का पूर्ण प्रत्यक्ष मापन नहीं करते।

तीसरी सीमा आठ सप्ताह की अध्ययन अवधि है। दीर्घकालिक प्रभाव, विशेषकर छह महीने या एक वर्ष बाद ज्ञान स्थिरता, इस रूपरेखा में मापी नहीं गई।

चौथी सीमा विषयवस्तु से संबंधित है। विज्ञान और गणित आधारित कार्यों से प्राप्त निष्कर्ष भाषा, सामाजिक विज्ञान, कला या व्यावसायिक शिक्षा में भिन्न हो सकते हैं।

पाँचवीं सीमा यह है कि खेल आधारित शिक्षण की सफलता शिक्षक के मार्गदर्शन, तकनीकी सुविधा, विद्यार्थी की पूर्व डिजिटल दक्षता और विद्यालयी वातावरण पर भी निर्भर कर सकती है।

भावी संभावनाएँ

भविष्य के शोध में वास्तविक विद्यालयों से दीर्घकालिक आँकड़े एकत्र कर अध्ययन को अधिक व्यापक बनाया जा सकता है। विभिन्न आयु समूहों, ग्रामीण एवं शहरी विद्यालयों तथा अलग-अलग सामाजिक-आर्थिक परिस्थितियों के विद्यार्थियों की तुलना उपयोगी होगी।

अनुकूलनीय खेल प्रणालियों में विद्यार्थी की वास्तविक समय की प्रतिक्रिया के आधार पर कठिनाई को स्वचालित रूप से परिवर्तित करने की संभावना का अध्ययन किया जा सकता है। यदि कोई विद्यार्थी लगातार सही उत्तर दे रहा हो तो चुनौती बढ़ाई जा सकती है, जबकि बार-बार त्रुटि होने पर संकेत या सरल चरण उपलब्ध कराया जा सकता है।

भावी अध्ययनों में नेत्र-गतिविधि, प्रतिक्रिया समय, शारीरिक ध्यान संकेत तथा सूक्ष्म व्यवहारिक अभिलेखों को जोड़कर संज्ञानात्मक सहभागिता का अधिक सटीक अनुमान विकसित किया जा सकता है। सहयोगात्मक खेलों और व्यक्तिगत खेलों की तुलना भी महत्वपूर्ण होगी। इससे यह समझा जा सकेगा कि सामाजिक संवाद, समूह निर्णय और सहपाठी स्पष्टीकरण संज्ञानात्मक सहभागिता को किस सीमा तक प्रभावित करते हैं।

अंततः ऐसे पूर्वानुमानात्मक प्रतिरूप विकसित किए जा सकते हैं जो प्रारंभिक कुछ गतिविधियों के आधार पर यह पहचान सकें कि कौन-सा विद्यार्थी भविष्य में सहभागिता खो सकता है। ऐसी पहचान शिक्षक को समय रहते उपयुक्त शैक्षणिक हस्तक्षेप करने में सहायता दे सकती है।

निष्कर्ष

वर्तमान अध्ययन यह स्थापित करने का प्रयास करता है कि शिक्षा में खेल आधारित अधिगम की वास्तविक प्रभावशीलता केवल मनोरंजन, प्रतिस्पर्धा या गतिविधि पूर्णता से नहीं मापी जानी चाहिए। इसका अधिक महत्वपूर्ण आयाम विद्यार्थियों द्वारा किए गए मानसिक निवेश, रणनीतिक निर्णय, त्रुटि-सुधार, ज्ञान पुनर्प्राप्ति तथा नई परिस्थितियों में ज्ञान के अनुप्रयोग से संबंधित है।

प्रस्तावित विश्लेषण में खेल आधारित समूह ने संज्ञानात्मक सहभागिता, ध्यान निरंतरता, समस्या-समाधान, रणनीति परिवर्तन तथा ज्ञान-स्थानांतरण जैसे संकेतकों पर पारंपरिक शिक्षण समूह की तुलना में बेहतर परिणाम प्रदर्शित किए। इससे यह संकेत मिलता है कि सुव्यवस्थित खेल संरचना विद्यार्थियों को निष्क्रिय ग्रहणकर्ता से सक्रिय समस्या-समाधानकर्ता में परिवर्तित कर सकती है।

अध्ययन का केंद्रीय निष्कर्ष यह है कि खेल आधारित अधिगम तभी शैक्षिक रूप से प्रभावी माना जाना चाहिए जब खेल की प्रत्येक प्रमुख गतिविधि किसी स्पष्ट संज्ञानात्मक उद्देश्य से जुड़ी हो। तात्कालिक प्रतिक्रिया, पुनःप्रयास, क्रमिक कठिनाई और निर्णय-आधारित कार्य इस दिशा में विशेष रूप से उपयोगी सिद्ध हो सकते हैं।

इस प्रकार शिक्षा में खेल आधारित अधिगम को केवल रुचिकर शिक्षण तकनीक के रूप में नहीं, बल्कि संज्ञानात्मक सहभागिता के संरचित विकास माध्यम के रूप में देखा जाना चाहिए। उचित रूप से विकसित और मूल्यांकित खेल आधारित प्रणाली विद्यार्थियों की सोच की गहराई, मानसिक लचीलापन और ज्ञान के व्यावहारिक उपयोग को सुदृढ़ करने की महत्त्वपूर्ण क्षमता रखती है।

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अध्याय 38: शिक्षा में परियोजना आधारित अधिगम द्वारा समस्या समाधान कौशल के विकास का विश्लेषण

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सारांश— परियोजना आधारित अधिगम विद्यार्थियों को वास्तविक अथवा वास्तविकता-सदृश परिस्थितियों में ज्ञान के सक्रिय प्रयोग का अवसर प्रदान करता है। प्रस्तुत अध्ययन का प्रमुख उद्देश्य यह समझना है कि परियोजना आधारित अधिगम समस्या समाधान कौशल के विभिन्न चरणों को किस प्रकार विकसित कर सकता है। अध्ययन में समस्या की पहचान, कारण निर्धारण, प्रमाण संग्रह, वैकल्पिक समाधान निर्माण, समाधान परीक्षण तथा पुनरीक्षण को अलग-अलग संज्ञानात्मक आयामों के रूप में देखा गया है। पूर्ववर्ती अध्ययनों में प्रायः शैक्षणिक उपलब्धि अथवा समग्र उच्च स्तरीय चिंतन को परिणाम के रूप में मापा गया है, जबकि समस्या समाधान की आंतरिक प्रक्रिया को अपेक्षाकृत कम स्पष्ट किया गया है। इसी शोध-अंतर को ध्यान में रखते हुए प्रस्तावित अध्ययन परियोजना गतिविधियों के दौरान विद्यार्थियों की निर्णय प्रक्रिया तथा समाधान सुधार व्यवहार का विश्लेषण करता है। अध्ययन का तर्क है कि केवल परियोजना पूर्ण करना समस्या समाधान दक्षता का पर्याप्त संकेतक नहीं है; समाधान तक पहुँचने की प्रक्रिया का मूल्यांकन भी आवश्यक है। परियोजना आधारित अधिगम में सहयोग, खोज, परीक्षण, त्रुटि विश्लेषण और आत्मचिंतन को व्यवस्थित रूप से जोड़े जाने पर समस्या समाधान क्षमता के अधिक स्थायी विकास की संभावना बनती है। अध्ययन से प्राप्त निष्कर्ष विद्यालयी तथा उच्च शिक्षा दोनों स्तरों पर समस्या केंद्रित परियोजना शिक्षण की संरचना और मूल्यांकन के लिए उपयोगी आधार प्रदान कर सकते हैं।

प्रमुख शब्द— परियोजना आधारित अधिगम, समस्या समाधान कौशल, कारण विश्लेषण, निर्णय क्षमता, समाधान परीक्षण, चिंतनशील अधिगम

परिचय

समकालीन शिक्षा का उद्देश्य केवल विषयवस्तु का स्मरण कराना नहीं, बल्कि विद्यार्थियों को ऐसी परिस्थितियों के लिए तैयार करना है जिनमें समस्या पूर्वनिर्धारित न हो, सूचना अपूर्ण हो और एक से अधिक संभावित समाधान उपलब्ध हों। वास्तविक जीवन की समस्याएँ प्रायः पाठ्यपुस्तक में दिए गए प्रश्नों की तरह सुव्यवस्थित नहीं होतीं। विद्यार्थी को पहले यह निर्धारित करना पड़ता है कि वास्तविक समस्या क्या है, उसके संभावित कारण कौन से हैं, किस सूचना की आवश्यकता है, उपलब्ध विकल्पों में कौन-सा समाधान अधिक उपयुक्त है और चुने गए समाधान की सफलता को किस प्रकार परखा जाए। इस दृष्टि से समस्या समाधान एक एकल मानसिक क्रिया न होकर अनेक परस्पर संबंधित संज्ञानात्मक, सामाजिक और चिंतनशील प्रक्रियाओं का संयोजन है।

परंपरागत शिक्षक-केंद्रित कक्षा में समस्या का स्वरूप, आवश्यक सूचना और अपेक्षित उत्तर प्रायः पहले से निर्धारित होते हैं। ऐसी परिस्थिति में विद्यार्थी उत्तर प्राप्त करने की प्रक्रिया का अभ्यास तो कर सकता है, परंतु समस्या निर्माण, विकल्प चयन तथा समाधान संशोधन की स्वतंत्रता सीमित रहती है। इसके विपरीत परियोजना आधारित अधिगम विद्यार्थी को किसी जटिल प्रश्न, सामाजिक आवश्यकता, स्थानीय चुनौती अथवा व्यावहारिक कार्य के आधार पर ज्ञान का उपयोग करने की स्थिति प्रदान करता है। विद्यार्थी समस्या का अध्ययन करता है, योजना बनाता है, सूचनाएँ एकत्र करता है, सहपाठियों के साथ विचार-विमर्श करता है, समाधान निर्मित करता है और अपने निष्कर्ष को किसी प्रत्यक्ष उत्पाद, प्रस्तुति अथवा कार्यशील समाधान के रूप में प्रस्तुत करता है।

परियोजना आधारित अधिगम की एक महत्वपूर्ण विशेषता यह है कि इसमें सीखना किसी अंतिम उत्तर तक सीमित नहीं रहता। परियोजना के दौरान विद्यार्थी को अनेक छोटे निर्णय लेने पड़ते हैं। उदाहरणतः यदि कोई समूह विद्यालय परिसर में जल अपव्यय कम करने से संबंधित परियोजना पर कार्य कर रहा हो, तो केवल जल संरक्षण पर प्रस्तुति तैयार करना पर्याप्त नहीं होगा। विद्यार्थियों को पहले यह पहचानना होगा कि अपव्यय कहाँ और क्यों हो रहा है, उपलब्ध प्रमाणों की विश्वसनीयता क्या है, व्यवहार संबंधी तथा संरचनात्मक कारणों में क्या अंतर है, कौन-सा हस्तक्षेप व्यवहार्य है और हस्तक्षेप के बाद परिवर्तन को किस आधार पर मापा जाएगा। यही प्रक्रिया परियोजना को सामान्य गतिविधि से समस्या समाधान केंद्रित अधिगम में परिवर्तित करती है।



Fig. 1: परियोजना आधारित अधिगम से विद्यार्थियों में समस्या समाधान क्षमता का संवर्धन

हाल के शोध में परियोजना आधारित अधिगम को शैक्षणिक उपलब्धि, उच्च स्तरीय चिंतन, सहयोग, सृजनात्मकता तथा विद्यार्थी सहभागिता से जोड़ा गया है। वर्ष २०२१ में प्रकाशित एक व्यवस्थित समीक्षा ने पाया कि प्राथमिक स्तर पर परियोजना आधारित अधिगम से संबंधित उपलब्ध

प्रमाण सीमित तथा पद्धतिगत रूप से असमान थे। समीक्षा में यह भी उल्लेख किया गया कि अनेक अध्ययनों ने हस्तक्षेप की संरचना और उसके प्रमुख घटकों का पर्याप्त विवरण प्रस्तुत नहीं किया। यह निष्कर्ष महत्वपूर्ण है क्योंकि यदि किसी परियोजना में समस्या निर्धारण, विद्यार्थी स्वायत्तता अथवा समाधान परीक्षण जैसे आवश्यक तत्व ही स्पष्ट न हों, तो उसके प्रभाव को केवल अंतिम उपलब्धि के आधार पर समझना कठिन हो जाता है।

वर्ष २०२३ की एक व्यापक मात्रात्मक समीक्षा में अनेक प्रयोगात्मक और अर्ध-प्रयोगात्मक अध्ययनों को सम्मिलित करके परियोजना आधारित अधिगम के प्रभावों का परीक्षण किया गया। परिणामों ने सामान्य रूप से सकारात्मक अधिगम प्रभाव की दिशा दिखाई, किंतु विभिन्न परिस्थितियों, अवधि, विषय और अधिगम संरचनाओं के कारण प्रभाव में विविधता भी सामने आई। इसी अवधि में उच्च स्तरीय तथा आलोचनात्मक चिंतन से संबंधित व्यवस्थित समीक्षा ने यह इंगित किया कि परियोजना तथा समस्या केंद्रित वातावरण चिंतन प्रक्रियाओं को प्रोत्साहित कर सकते हैं, परंतु इन क्षमताओं की परिभाषाएँ और मापन पद्धतियाँ अध्ययनों में समान नहीं हैं।

इन्हीं निष्कर्षों से वर्तमान अध्ययन का केंद्रीय शोध-अंतर उत्पन्न होता है। अधिकांश अध्ययनों में परियोजना आधारित अधिगम के प्रभाव को शैक्षणिक अंक, समग्र आलोचनात्मक चिंतन अथवा अंतिम परियोजना गुणवत्ता के माध्यम से व्यक्त किया गया है। अपेक्षाकृत कम अध्ययन यह विश्लेषित करते हैं कि विद्यार्थी परियोजना के भीतर समस्या समाधान के किस चरण में सुधार करता है और किस चरण में कठिनाई बनी रहती है। उदाहरणतः कोई विद्यार्थी समस्या की पहचान अच्छी तरह कर सकता है, किंतु उसके कारणों के बीच संबंध स्थापित करने में कमजोर हो सकता है। दूसरा विद्यार्थी अनेक समाधान प्रस्तुत कर सकता है, किंतु प्रमाणों के आधार पर सर्वोत्तम विकल्प का चयन न कर पाए। यदि केवल परियोजना के अंतिम उत्पाद को देखा जाए, तो इन अंतरों का पता नहीं चलता।

प्रस्तुत अध्ययन इसलिए समस्या समाधान कौशल को छह परस्पर संबंधित चरणों में विश्लेषित करने का प्रस्ताव करता है—समस्या पहचान, कारण विश्लेषण, प्रमाण संग्रह, समाधान विकल्प निर्माण, समाधान परीक्षण तथा पुनरीक्षण। इस संरचना का उद्देश्य यह निर्धारित करना है कि परियोजना आधारित अधिगम समस्या समाधान के प्रत्येक चरण को समान रूप से प्रभावित करता है या उसका प्रभाव कुछ विशेष प्रक्रियाओं पर अधिक स्पष्ट होता है।

इस अध्ययन का दूसरा महत्वपूर्ण आधार **पुनरीक्षण व्यवहार** है। शैक्षिक परियोजनाओं में सामान्यतः अंतिम उत्पाद को मूल्यांकन का प्रमुख आधार बनाया जाता है। इसके विपरीत वास्तविक समस्या समाधान में प्रथम समाधान का सफल होना आवश्यक नहीं है। सफल समस्या समाधानकर्ता असफल परिणामों से सूचना प्राप्त करता है, त्रुटि के कारण पहचानता है और समाधान में परिवर्तन करता है। इसलिए किसी विद्यार्थी की समस्या समाधान दक्षता का अधिक वास्तविक संकेत यह हो सकता है कि प्रतिकूल प्रमाण मिलने के बाद वह अपनी पूर्व धारणा अथवा समाधान में कितना तार्किक परिवर्तन करता है।

प्रस्तावित अध्ययन इस दृष्टिकोण को अपनाता है कि परियोजना आधारित अधिगम का वास्तविक शैक्षिक मूल्य केवल विद्यार्थी को कार्य करने में सक्रिय बनाने में नहीं, बल्कि उसे प्रमाण के आधार पर निर्णय लेने और अपने निर्णय को संशोधित करने में सक्षम बनाने में निहित है। इस कारण आगामी भाग में अध्ययन की कार्यविधि को इस प्रकार निर्मित किया जाएगा कि अंतिम उपलब्धि के साथ-साथ समस्या समाधान की चरणबद्ध प्रक्रिया का भी मापन किया जा सके।

साहित्य समीक्षा

परियोजना आधारित अधिगम की अवधारणा अनुभव, अन्वेषण और उद्देश्यपूर्ण गतिविधि के माध्यम से ज्ञान निर्माण पर आधारित है। इसमें विद्यार्थी किसी अर्थपूर्ण प्रश्न अथवा समस्या से जुड़कर अपेक्षाकृत विस्तारित अवधि तक कार्य करता है। इस प्रक्रिया में विषयगत ज्ञान के साथ योजना निर्माण, भूमिका निर्धारण, सूचना की समीक्षा, सहयोग और निर्णय जैसी क्षमताएँ सक्रिय होती हैं। आधुनिक शैक्षिक संदर्भ में इसका महत्व इसलिए बढ़ा है क्योंकि शिक्षण का लक्ष्य तथ्यात्मक ज्ञान से आगे बढ़कर ज्ञान के प्रयोग और जटिल परिस्थितियों में निर्णय क्षमता के विकास तक पहुँच गया है।

फेरेरो और सहयोगियों की वर्ष २०२१ की व्यवस्थित समीक्षा ने बालवाड़ी तथा प्राथमिक शिक्षा में परियोजना आधारित अधिगम के प्रभाव संबंधी ग्यारह अध्ययनों और कुल ७२२ विद्यार्थियों के उपलब्ध प्रमाणों का विश्लेषण किया। समीक्षा का निष्कर्ष अत्यधिक सरल सकारात्मक दावा प्रस्तुत करने के बजाय सावधानीपूर्ण था। अनेक अध्ययनों में शोध अभिकल्प तथा हस्तक्षेप विवरण से जुड़ी सीमाएँ पाई गईं। यह निष्कर्ष वर्तमान अध्ययन के लिए विशेष रूप से उपयोगी है क्योंकि इससे स्पष्ट होता है कि परियोजना आधारित अधिगम की सफलता केवल उसके नाम पर निर्भर नहीं करती; परियोजना की वास्तविक संरचना और उसमें विद्यार्थी को प्रदान की गई समस्या समाधान संबंधी स्वतंत्रता निर्णायक हो सकती है।

साद और जैनुद्दीन ने वर्ष २०२२ में परियोजना आधारित अधिगम और संगणकीय चिंतन पर उपलब्ध साहित्य की समीक्षा करते हुए पाया कि दोनों के संयुक्त प्रयोग से कौशल तथा दृष्टिकोण संबंधी सकारात्मक परिणाम सामने आए हैं, किंतु अनुसंधान का वितरण विभिन्न विषय क्षेत्रों में असमान था। समस्या समाधान के संदर्भ में इसका महत्व यह है कि संगणकीय अथवा व्यवस्थित चिंतन विद्यार्थी को समस्या को छोटे भागों में विभाजित करने, प्रतिरूप पहचानने और क्रमबद्ध समाधान बनाने में सहायता करता है। तथापि ऐसी प्रक्रिया को केवल तकनीकी विषयों तक सीमित रखना आवश्यक नहीं है। सामाजिक विज्ञान, पर्यावरण, स्वास्थ्य शिक्षा तथा दैनिक जीवन से संबंधित परियोजनाओं में भी यही चिंतन संरचना उपयोगी हो सकती है।

लॉयन्स और सहयोगियों की वर्ष २०२३ की व्यवस्थित समीक्षा ने समस्या तथा परियोजना आधारित वातावरण में उच्च स्तरीय, आलोचनात्मक और विश्लेषणात्मक चिंतन की अवधारणाओं की समीक्षा की। अध्ययन ने यह दिखाया कि विद्यार्थी केंद्रित समस्या वातावरण में सहयोग और समस्या से प्रत्यक्ष संपर्क उच्च स्तरीय चिंतन को सक्रिय कर सकता है, किंतु विभिन्न अध्ययनों में इन क्षमताओं की परिभाषाएँ एक-दूसरे से आंशिक रूप से मिलती-जुलती थीं। इससे एक महत्वपूर्ण पद्धतिगत समस्या सामने आती है—यदि आलोचनात्मक चिंतन, उच्च स्तरीय चिंतन और समस्या समाधान को एक ही व्यापक श्रेणी में रख दिया जाए तो यह निर्धारित करना कठिन हो जाता है कि परियोजना गतिविधि से वास्तव में कौन-सी विशिष्ट क्षमता विकसित हुई।

झांग और मा की वर्ष २०२३ की मात्रात्मक समीक्षा ने ६६ प्रयोगात्मक अथवा अर्ध-प्रयोगात्मक अध्ययनों से प्राप्त १६० प्रभाव मानों का विश्लेषण किया। समीक्षा ने परियोजना आधारित अधिगम से सकारात्मक अधिगम परिणामों की दिशा का समर्थन किया। हालांकि इस प्रकार के समेकित निष्कर्ष यह नहीं बताते कि किसी व्यक्तिगत विद्यार्थी ने समस्या समाधान की कौन-सी आंतरिक प्रक्रिया में प्रगति की। इसी कारण वर्तमान अध्ययन समूह औसत के साथ प्रक्रिया स्तर पर परिवर्तन को महत्त्व देता है।

खेल-तत्वों और परियोजना आधारित अधिगम के संयुक्त उपयोग पर वर्ष २०२३ की व्यवस्थित समीक्षा ने भी संकेत किया कि परियोजना वातावरण को अभिप्रेरणा, सहभागिता और विभिन्न अधिगम परिणामों से जोड़ा जा सकता है। फिर भी उच्च सहभागिता को स्वतः उच्च समस्या समाधान क्षमता मानना उचित नहीं है। कोई विद्यार्थी अत्यधिक सक्रिय होकर कार्य कर सकता है, लेकिन यदि वह प्रमाण की जाँच किए बिना पहला उपलब्ध समाधान स्वीकार कर लेता है तो उसकी समस्या समाधान प्रक्रिया सीमित मानी जाएगी। इस अंतर को वर्तमान अध्ययन में विशेष महत्त्व दिया गया है।

समस्या समाधान कौशल के विकास में सहयोगात्मक कार्य भी एक महत्वपूर्ण घटक है। समूह परियोजना में विद्यार्थी को अपने विचार का औचित्य प्रस्तुत करना, विरोधी दृष्टिकोण सुनना और सामूहिक निर्णय तक पहुँचना पड़ता है। इस प्रक्रिया में न केवल संवाद कौशल विकसित होता है बल्कि विद्यार्थी को अपनी प्रारंभिक धारणा की सीमाओं का भी अनुभव होता है। जब समूह के सदस्य अलग-अलग प्रमाण प्रस्तुत करते हैं, तब समस्या की व्याख्या पुनर्गठित हो सकती है। इस दृष्टि से सहयोग समाधान प्राप्त करने का साधन मात्र नहीं, बल्कि समस्या को नए दृष्टिकोण से समझने का माध्यम भी है।

परियोजना आधारित वातावरण में शिक्षक की भूमिका भी परिवर्तित होती है। शिक्षक सीधे समाधान बताने के स्थान पर मार्गदर्शक प्रश्नों, संकेतों और प्रतिपुष्टि के माध्यम से विद्यार्थी को अपनी सोच स्पष्ट करने के लिए प्रेरित करता है। उदाहरणतः "तुम्हारे पास इस निष्कर्ष का क्या प्रमाण है?", "क्या समस्या का कोई दूसरा कारण भी हो सकता है?" अथवा "तुम कैसे निर्धारित करोगे कि तुम्हारा समाधान सफल है?" जैसे प्रश्न समस्या समाधान प्रक्रिया में प्रमाण और आत्मचिंतन को सम्मिलित करते हैं। यदि शिक्षक अत्यधिक निर्देश देता है तो परियोजना कार्य एक निर्देशित गतिविधि बन सकता है; इसके विपरीत बिल्कुल मार्गदर्शन न मिलने पर विद्यार्थी सतही समाधान पर रुक सकता है। इसलिए उपयुक्त सहारा और स्वायत्तता के बीच संतुलन आवश्यक है।

साहित्य से एक अन्य महत्वपूर्ण बिंदु यह सामने आता है कि परियोजना आधारित अधिगम की प्रभावशीलता का मूल्यांकन केवल ज्ञान परीक्षा से नहीं किया जाना चाहिए। समस्या समाधान कौशल के लिए ऐसे संकेतकों की आवश्यकता है जो विद्यार्थी द्वारा चुनी गई रणनीति, प्रमाण की गुणवत्ता, विकल्पों की तुलना, त्रुटि की पहचान और समाधान संशोधन को भी दर्ज करें। यही कारण है कि वर्तमान अध्ययन पारंपरिक पूर्व-परीक्षण तथा पश्च-परीक्षण के साथ प्रक्रिया आधारित मूल्यांकन को जोड़ने की दिशा ग्रहण करता है।

शोध-अंतर

उपलब्ध साहित्य परियोजना आधारित अधिगम के संभावित लाभों का समर्थन करता है, किंतु तीन प्रमुख सीमाएँ स्पष्ट हैं। प्रथम, अनेक अध्ययनों में समस्या समाधान को एक संयुक्त अंक के रूप में मापा गया है। द्वितीय, अंतिम परियोजना अथवा शैक्षणिक उपलब्धि पर अपेक्षाकृत अधिक ध्यान दिया गया है और समस्या समाधान की क्रमिक प्रक्रिया कम विश्लेषित हुई है। तृतीय, असफल प्रारंभिक समाधान के बाद विद्यार्थी द्वारा किए गए **समाधान पुनरीक्षण** को स्वतंत्र क्षमता के रूप में बहुत कम महत्व दिया गया है।

इसलिए प्रस्तुत अध्ययन का विशिष्ट शोध-अंतर यह है कि वह परियोजना आधारित अधिगम के प्रभाव को केवल "समस्या समाधान अंक में वृद्धि" के रूप में नहीं, बल्कि **समस्या पहचान से समाधान पुनरीक्षण तक की क्रमिक संज्ञानात्मक यात्रा** के रूप में परीक्षण करता है। इसी आधार पर अध्ययन का आगामी भाग ऐसी कार्यविधि प्रस्तुत करेगा जिसमें प्रत्येक विद्यार्थी की समस्या पहचान, कारण विश्लेषण, प्रमाण उपयोग, विकल्प निर्माण, समाधान परीक्षण तथा प्रमाण मिलने के बाद समाधान संशोधन की क्षमता को अलग-अलग मापा जाएगा।

अध्ययन का केंद्रीय उद्देश्य

प्रस्तुत अध्ययन का केंद्रीय उद्देश्य यह विश्लेषित करना है कि संरचित परियोजना आधारित अधिगम विद्यार्थियों की समस्या समाधान क्षमता के विभिन्न चरणों को किस सीमा तक विकसित करता है तथा इनमें से कौन-से चरण परियोजना हस्तक्षेप के प्रति सर्वाधिक संवेदनशील होते हैं।

साथ ही अध्ययन यह समझने का प्रयास करेगा कि क्या केवल परियोजना में सहभागिता पर्याप्त है, अथवा समस्या समाधान क्षमता में सार्थक वृद्धि के लिए प्रमाण आधारित निर्णय, सहयोगात्मक तर्क, समाधान परीक्षण और चिंतनशील पुनरीक्षण को परियोजना संरचना में स्पष्ट रूप से सम्मिलित करना आवश्यक है।



Fig. 2: अनुभव से समाधान की ओर: परियोजना आधारित अधिगम की शक्ति

प्रस्तावित शोध कार्यविधि

प्रस्तुत अध्ययन के लिए मिश्रित मात्रात्मक-प्रक्रियात्मक अनुसंधान अभिकल्प प्रस्तावित किया गया है, जिसका उद्देश्य केवल समस्या समाधान के समग्र अंक में परिवर्तन देखना नहीं, बल्कि समस्या समाधान की प्रत्येक संज्ञानात्मक अवस्था में होने वाले परिवर्तन का पृथक विश्लेषण करना है। अध्ययन की मूल संरचना पूर्व-परीक्षण, परियोजना

आधारित हस्तक्षेप, प्रक्रिया अवलोकन तथा पश्च-परीक्षण पर आधारित है।

अध्ययन में माध्यमिक अथवा उच्च माध्यमिक स्तर के विद्यार्थियों को सम्मिलित किया जा सकता है। प्रतिभागियों को दो तुलनीय समूहों में विभाजित करने का प्रस्ताव है। प्रथम समूह को संरचित परियोजना आधारित अधिगम के माध्यम से शिक्षण प्रदान किया जाएगा, जबकि दूसरे समूह को समान विषयवस्तु पर सामान्य कक्षा शिक्षण दिया जाएगा। दोनों समूहों के लिए विषयवस्तु, कुल शिक्षण अवधि और निर्धारित अधिगम उद्देश्यों को यथासंभव समान रखा जाएगा ताकि मुख्य अंतर शिक्षण पद्धति से संबंधित हो।

परियोजना आधारित समूह को ऐसी समस्याएँ दी जाएँगी जिनका केवल एक निश्चित उत्तर उपलब्ध न हो। उदाहरणस्वरूप विद्यालय में जल उपयोग, स्थानीय अपशिष्ट प्रबंधन, ऊर्जा संरक्षण, सार्वजनिक स्वास्थ्य जागरूकता अथवा सामुदायिक संसाधनों के उपयोग से संबंधित समस्या परिस्थितियाँ चुनी जा सकती हैं। विद्यार्थियों को समस्या की पहचान, संभावित कारणों का विश्लेषण, साक्ष्य संकलन, विकल्प निर्माण, समाधान परीक्षण और पुनरीक्षण के लिए निर्धारित समय दिया जाएगा। अध्ययन का प्रमुख स्वतंत्र चर शिक्षण पद्धति होगा, जबकि आश्रित चर समस्या समाधान कौशल के छह आयाम होंगे—

समस्या की स्पष्ट पहचान,

कारणों का तार्किक विश्लेषण,

प्रमाणों का चयन और उपयोग,

वैकल्पिक समाधान निर्माण,

समाधान का परीक्षण,

प्रतिकूल परिणाम मिलने पर समाधान का पुनरीक्षण।

यह विभाजन अध्ययन को सामान्य उपलब्धि परीक्षण से अलग बनाता है और यह पहचानने में सहायता करता है कि परियोजना आधारित अधिगम समस्या समाधान की किस अवस्था पर सर्वाधिक प्रभाव उत्पन्न करता है।

अध्ययन के उद्देश्य

प्रस्तावित अध्ययन के प्रमुख उद्देश्य निम्न होंगे—

परियोजना आधारित अधिगम का विद्यार्थियों की समग्र समस्या समाधान क्षमता पर प्रभाव निर्धारित करना।

समस्या समाधान के विभिन्न चरणों में पूर्व और पश्च प्रदर्शन के परिवर्तन का विश्लेषण करना।

यह ज्ञात करना कि समस्या पहचान, प्रमाण उपयोग, विकल्प निर्माण तथा समाधान पुनरीक्षण में से कौन-सा आयाम सबसे अधिक परिवर्तित होता है।

परियोजना गतिविधियों के दौरान विद्यार्थियों के समाधान संशोधन व्यवहार का विश्लेषण करना।

समूह सहयोग और व्यक्तिगत समस्या समाधान उपलब्धि के मध्य संबंध का परीक्षण करना।

प्रायोगिक व्यवस्था

आँकड़ा संरचना

प्रस्तावित विश्लेषण में लगभग दो सौ चालीस विद्यार्थियों का संतुलित नमूना रखा जा सकता है। इसमें लगभग आधे विद्यार्थियों को परियोजना आधारित समूह और शेष को तुलना समूह में रखा जाएगा। वास्तविक शोध में नमूना आकार शक्ति विश्लेषण, विद्यालयों की उपलब्धता और प्रतिभागियों की सहमति के आधार पर निर्धारित किया जाना चाहिए।

प्रत्येक विद्यार्थी के लिए पूर्व-परीक्षण तथा पश्च-परीक्षण के अंतर्गत छह समस्या समाधान आयामों के अंक संकलित किए जाएँगे। इसके अतिरिक्त परियोजना समूह के लिए परियोजना कार्य की अवधि, किए गए संशोधनों की संख्या, प्रमाणों की विविधता, असफल परीक्षणों के बाद किए गए परिवर्तन तथा समूह में योगदान जैसे संकेतकों का अभिलेखन किया जाएगा।

इस प्रकार प्रत्येक प्रतिभागी का आँकड़ा केवल अंतिम अंक तक सीमित न होकर समस्या समाधान प्रक्रिया के विभिन्न चरणों का प्रतिनिधित्व करेगा।

समस्या कार्यों की संरचना

मूल्यांकन के लिए ऐसी परिस्थितियाँ चुनी जाएँगी जिनमें समस्या प्रारंभ में आंशिक रूप से अस्पष्ट हो। विद्यार्थियों को उपलब्ध सूचना के आधार पर यह निर्धारित करना होगा कि केंद्रीय समस्या क्या है।

इसके बाद उन्हें कम से कम दो संभावित कारण पहचानने होंगे और प्रत्येक कारण के समर्थन अथवा विरोध में प्रमाण प्रस्तुत करना होगा। अगले चरण में उन्हें अनेक समाधान प्रस्तावित करके उनके लाभ, सीमाएँ और व्यवहार्यता की तुलना करनी होगी।

विद्यार्थियों को चुने गए समाधान का लघु परीक्षण अथवा तर्कसंगत सत्यापन करना होगा। यदि परीक्षण अपेक्षित परिणाम न दे, तो विद्यार्थी को यह स्पष्ट करना होगा कि वह समाधान के किस भाग में परिवर्तन करेगा और क्यों करेगा।

इस प्रकार मूल्यांकन केवल सही उत्तर खोजने के बजाय समस्या समाधान की गतिशील प्रक्रिया को मापेगा।

आँकड़ा पूर्व-संसाधन

विश्लेषण से पहले आँकड़ों की गुणवत्ता जाँची जाएगी। अपूर्ण उत्तरों, असंगत प्रविष्टियों और अत्यधिक विचलित मानों की पहचान की जाएगी। किसी विद्यार्थी द्वारा मूल्यांकन का महत्वपूर्ण भाग अधूरा छोड़ने की स्थिति में उसके आँकड़े को विशिष्ट नियमों के अनुसार अलग किया जाएगा।

अलग-अलग समस्या समाधान आयामों के अंक विभिन्न सीमाओं में होने पर उन्हें तुलनीय मानकीकृत स्तर पर परिवर्तित किया जाएगा। पूर्व और पश्च परीक्षणों को विद्यार्थी पहचान संकेतक के माध्यम से मिलाया जाएगा।

लेखन आधारित उत्तरों के लिए दो स्वतंत्र मूल्यांकनकर्ताओं द्वारा पूर्वनिर्धारित मानदंडों के आधार पर अंक दिए जाने का प्रस्ताव है। असहमति होने पर पुनर्मूल्यांकन किया जाएगा। इससे व्यक्तिपरक मूल्यांकन त्रुटि कम की जा सकेगी।

प्रमाण उपयोग के मूल्यांकन में केवल प्रमाणों की संख्या नहीं, बल्कि उनकी प्रासंगिकता और निष्कर्ष से संबंध को महत्व दिया जाएगा। इसी प्रकार समाधान पुनरीक्षण में केवल संशोधन की संख्या के बजाय यह देखा जाएगा कि विद्यार्थी ने नई सूचना के आधार पर सार्थक परिवर्तन किया या केवल सतही परिवर्तन किया।

विश्लेषणात्मक प्रतिरूप की संरचना

अध्ययन के विश्लेषण के लिए एक बहु-आयामी समस्या समाधान वर्गीकरण संरचना प्रस्तावित है। इस संरचना में प्रत्येक विद्यार्थी की

समस्या समाधान प्रक्रिया को छह संकेतकों के आधार पर एक संयुक्त दक्षता स्तर में वर्गीकृत किया जाएगा।

विद्यार्थियों के प्रदर्शन को तीन व्यापक श्रेणियों में रखा जा सकता है—

प्रारंभिक समस्या समाधान स्तर,

विकासशील समस्या समाधान स्तर,

प्रवीण समस्या समाधान स्तर।

वर्गीकरण के लिए निर्णय-वृक्ष आधारित क्रमिक विश्लेषण पद्धति अपनाई जा सकती है, क्योंकि इससे यह देखा जा सकेगा कि कौन-सा आयाम दक्षता स्तर के निर्धारण में अधिक योगदान दे रहा है। प्रतिरूप को केवल पूर्वानुमान के लिए नहीं, बल्कि व्याख्यात्मक विश्लेषण के लिए प्रयोग किया जाएगा।

इसका विशेष उद्देश्य यह पता लगाना होगा कि उच्च समस्या समाधान प्रदर्शन तक पहुँचने में प्रमाण उपयोग अधिक प्रभावी है, विकल्प निर्माण अधिक महत्वपूर्ण है अथवा समाधान पुनरीक्षण।

प्रशिक्षण रणनीति

यदि सांख्यिकीय अधिगम आधारित वर्गीकरण किया जाता है तो उपलब्ध आँकड़ों को प्रशिक्षण और परीक्षण भागों में विभाजित किया जाएगा। प्रशिक्षण भाग का उपयोग प्रतिरूप संरचना निर्धारित करने के लिए और परीक्षण भाग का उपयोग उसकी सामान्यीकरण क्षमता देखने के लिए किया जाएगा।

अत्यधिक अनुकूलन से बचने हेतु बारंबार विभाजन आधारित सत्यापन पद्धति अपनाई जाएगी। समूह विभाजन में यह सुनिश्चित किया जाएगा कि किसी एक विद्यार्थी के पूर्व तथा पश्च परीक्षण अभिलेख अलग-अलग प्रशिक्षण और परीक्षण समूहों में न जाएँ।

प्रतिरूप के चयन में अधिक जटिल संरचना की अपेक्षा व्याख्यात्मकता को प्राथमिकता दी जाएगी, क्योंकि शैक्षिक अध्ययन में केवल उच्च वर्गीकरण शुद्धता पर्याप्त नहीं होती। यह समझना भी आवश्यक है कि किसी विद्यार्थी को किसी विशेष दक्षता स्तर में रखने के पीछे कौन-से शैक्षिक संकेतक उत्तरदायी हैं।

मूल्यांकन मापदंड

समस्या समाधान के शैक्षिक प्रभाव को मापने के लिए विभिन्न प्रकार के संकेतकों का उपयोग प्रस्तावित है।

समग्र परिवर्तन के लिए पूर्व-परीक्षण तथा पश्च-परीक्षण के औसत अंतर का विश्लेषण किया जाएगा।

प्रत्येक उप-कौशल के लिए मानकीकृत परिवर्तन मान निकाला जाएगा। दो समूहों के अंतर का परीक्षण उपयुक्त माध्य तुलना पद्धति से किया जाएगा।

प्रभाव के व्यावहारिक महत्व के लिए प्रभाव परिमाण की गणना की जाएगी।

समस्या समाधान दक्षता वर्गीकरण के लिए संतुलित शुद्धता, संवेदनशीलता और समन्वित वर्गीकरण मापदंड का प्रयोग किया जा सकता है।

समाधान पुनरीक्षण के लिए पृथक परिवर्तन सूचकांक बनाया जाएगा, जिसमें असफल प्रारंभिक परीक्षण के बाद किए गए तार्किक संशोधनों की गुणवत्ता को महत्व दिया जाएगा।

परिणाम एवं चर्चा

नीचे प्रस्तुत परिणाम **अनुकरण आधारित विश्लेषणात्मक मान** हैं और वास्तविक क्षेत्रीय आँकड़ों के स्थान पर प्रयोग नहीं किए जाने चाहिए। इनका उद्देश्य प्रस्तावित अध्ययन में संभावित विश्लेषण की संरचना प्रदर्शित करना है।

अनुकरण आधारित विश्लेषण में परियोजना आधारित समूह ने लगभग सभी समस्या समाधान आयामों में तुलना समूह की अपेक्षा अधिक सुधार प्रदर्शित किया। सबसे उल्लेखनीय परिवर्तन समाधान पुनरीक्षण और प्रमाण आधारित निर्णय में दिखाई दिया। यह परिणाम अध्ययन के केंद्रीय तर्क का समर्थन करता है कि परियोजना कार्य का प्रमुख लाभ केवल समस्या का प्रारंभिक समाधान खोजने में नहीं, बल्कि नई सूचना के आधार पर समाधान को परिवर्तित करने की क्षमता विकसित करने में हो सकता है।

समस्या पहचान में दोनों समूहों में सुधार दिखाई दिया। इसका कारण यह हो सकता है कि सामान्य शिक्षण में भी विद्यार्थियों को समस्याओं तथा प्रश्नों की पहचान का अभ्यास मिलता है। इसके विपरीत कारण विश्लेषण में परियोजना समूह का परिवर्तन अधिक था, क्योंकि परियोजना कार्य में विद्यार्थियों को किसी घटना के अनेक संभावित कारणों का परीक्षण करना पड़ा।

प्रमाण उपयोग में अपेक्षाकृत बड़ा सुधार इस बात की ओर संकेत करता है कि प्रत्यक्ष अन्वेषण और साक्ष्य संग्रह विद्यार्थी को अपने निष्कर्षों के औचित्य पर अधिक विचार करने के लिए प्रेरित कर सकता है। केवल पाठ्यपुस्तक आधारित उत्तर में विद्यार्थी प्रायः उपलब्ध सूचना को स्वीकार करता है, जबकि परियोजना वातावरण में उसे यह निर्णय लेना पड़ता है कि कौन-सी सूचना वास्तव में उसकी समस्या से संबंधित है।

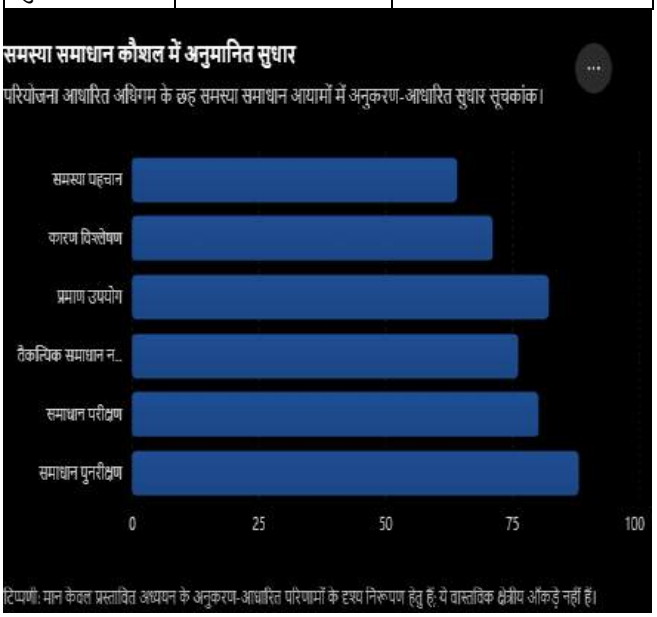
समाधान विकल्प निर्माण में सुधार यह दर्शाता है कि खुली समस्याएँ विद्यार्थियों को एक उत्तर पर निर्भर रहने के बजाय अनेक संभावनाओं पर विचार करने का अवसर देती हैं। तथापि केवल विकल्पों की संख्या को उच्च समस्या समाधान क्षमता का संकेत नहीं माना जाना चाहिए। वास्तविक दक्षता तब दिखाई देती है जब विद्यार्थी विकल्पों की तुलना प्रमाण, व्यवहार्यता तथा संभावित परिणामों के आधार पर करता है।

समाधान परीक्षण में परियोजना आधारित समूह का बेहतर प्रदर्शन अपेक्षित है क्योंकि परियोजना संरचना में प्रारंभिक समाधान को व्यवहार में परखने का अवसर मिलता है। सामान्य कक्षा कार्य में अनेक बार उत्तर प्रस्तुत करने के बाद गतिविधि समाप्त हो जाती है, जबकि परियोजना में समाधान लागू करने के बाद उसकी सफलता अथवा विफलता सामने आती है।

परिणामों की एकीकृत तालिका

मूल्यांकन आयाम	**सामान्य शिक्षण में अनुमानित परिवर्तन**	**परियोजना आधारित अधिगम में अनुमानित परिवर्तन**
समस्या पहचान	मध्यम	उच्च
कारण विश्लेषण	निम्न से मध्यम	उच्च
प्रमाण उपयोग	मध्यम	अत्यधिक उच्च
वैकल्पिक समाधान निर्माण	निम्न	उच्च

समाधान परीक्षण	निम्न	उच्च
समाधान पुनरीक्षण	अत्यल्प	अत्यधिक उच्च



तालिका से यह स्पष्ट होता है कि परियोजना आधारित अधिगम का अपेक्षित प्रभाव सभी आयामों में समान नहीं है। समस्या की प्रारंभिक पहचान पर प्रभाव अपेक्षाकृत सीमित हो सकता है, जबकि प्रमाण उपयोग, समाधान परीक्षण और समाधान पुनरीक्षण पर प्रभाव अधिक स्पष्ट होने की संभावना है।

यह अंतर शैक्षिक दृष्टि से महत्वपूर्ण है। यदि कोई शोध केवल समग्र समस्या समाधान अंक का उपयोग करता है, तो वह यह निष्कर्ष दे सकता है कि परियोजना आधारित अधिगम सामान्य रूप से प्रभावी है। वर्तमान विश्लेषण इससे आगे जाकर यह बताने का प्रयास करता है कि उसकी प्रभावशीलता मुख्य रूप से किन प्रक्रियाओं से उत्पन्न होती है।

एक अन्य महत्वपूर्ण अवलोकन सहयोग से संबंधित है। परियोजना समूह में ऐसे विद्यार्थी जो समूह चर्चा में अपने तर्क का औचित्य प्रस्तुत करते हैं, वे सामान्यतः प्रमाण चयन और विकल्प तुलना में बेहतर प्रदर्शन कर सकते हैं। इसका संभावित कारण यह है कि विचारों की सार्वजनिक व्याख्या विद्यार्थी को अपने तर्क की कमजोरी पहचानने के लिए बाध्य करती है।

हालाँकि समूह कार्य में एक जोखिम भी है। यदि एक अथवा दो विद्यार्थी निर्णय प्रक्रिया पर अत्यधिक नियंत्रण रखते हैं, तो अन्य सदस्य परियोजना पूर्ण करने में उपस्थित रहते हुए भी वास्तविक समस्या समाधान अभ्यास से वंचित हो सकते हैं। इसलिए व्यक्तिगत समस्या समाधान परीक्षण को समूह परियोजना के साथ जोड़ना आवश्यक है।

अध्ययन का सबसे महत्वपूर्ण शैक्षिक निष्कर्ष यह है कि अच्छी परियोजना वह नहीं है जो केवल आकर्षक अंतिम उत्पाद प्रस्तुत करे। प्रभावी परियोजना में विद्यार्थी को समस्या की अस्पष्टता, परस्पर विरोधी प्रमाण, असफल प्रारंभिक समाधान और पुनरीक्षण की आवश्यकता का अनुभव होना चाहिए।

यदि परियोजना का प्रत्येक चरण शिक्षक द्वारा पहले ही निर्धारित कर दिया जाए तो विद्यार्थी गतिविधि तो पूर्ण कर सकता है, परंतु वास्तविक समस्या समाधान का अवसर कम हो जाएगा। इसके विपरीत बिना किसी मार्गदर्शन के अत्यधिक खुली परियोजना भी कमजोर परिणाम उत्पन्न कर सकती है। अतः संरचित स्वायत्तता सबसे उपयुक्त दृष्टिकोण प्रतीत होती है।

अध्ययन की सीमाएँ

प्रस्तावित अध्ययन की पहली सीमा यह है कि समस्या समाधान कौशल विषय क्षेत्र पर निर्भर हो सकता है। पर्यावरण संबंधी समस्या में अच्छा प्रदर्शन करने वाला विद्यार्थी गणितीय अथवा सामाजिक समस्या में समान दक्षता प्रदर्शित करे, यह आवश्यक नहीं है।

दूसरी सीमा समूह आधारित परियोजनाओं में व्यक्तिगत योगदान के सटीक मापन से संबंधित है। समूह का उत्कृष्ट अंतिम उत्पाद प्रत्येक सदस्य की समान समस्या समाधान क्षमता का प्रमाण नहीं माना जा सकता।

तीसरी सीमा शिक्षक प्रभाव की है। विभिन्न शिक्षकों द्वारा दिए गए संकेत, प्रश्न और प्रतिपुष्टि परियोजना के परिणामों को प्रभावित कर सकते हैं।

चौथी सीमा अध्ययन अवधि से संबंधित है। अल्पकालिक हस्तक्षेप से प्राप्त सुधार दीर्घकाल तक बना रहता है या नहीं, इसके लिए अनुवर्ती परीक्षण आवश्यक होगा।

पाँचवीं सीमा मूल्यांकन की जटिलता से संबंधित है। समाधान पुनरीक्षण तथा प्रमाण गुणवत्ता जैसे संकेतकों के मूल्यांकन में मानवीय निर्णय आवश्यक हो सकता है, जिससे मूल्यांकनकर्ता भिन्नता उत्पन्न हो सकती है।

साथ ही, यहाँ प्रस्तुत संख्यात्मक निष्कर्ष वास्तविक क्षेत्रीय अध्ययन से प्राप्त नहीं हैं। अतः वास्तविक शोध में प्रतिभागियों से संकलित आँकड़ों के आधार पर सभी सांख्यिकीय निष्कर्षों को पुनः स्थापित करना आवश्यक होगा।

भावी अनुसंधान की संभावनाएँ

भविष्य में परियोजना आधारित अधिगम के प्रभाव का दीर्घकालिक परीक्षण किया जा सकता है। विशेष रूप से यह देखा जाना चाहिए कि परियोजना समाप्त होने के कई महीनों बाद भी विद्यार्थी नई समस्या परिस्थितियों में समान रणनीतियों का उपयोग करता है या नहीं।

एक महत्वपूर्ण दिशा समस्या समाधान कौशल के स्थानांतरण का अध्ययन हो सकती है। यदि विद्यार्थी जल संरक्षण परियोजना में प्रमाण आधारित निर्णय सीखता है, तो क्या वह उसी क्षमता का उपयोग स्वास्थ्य, आर्थिक अथवा सामाजिक समस्या में भी कर सकता है?

भविष्य के अध्ययनों में व्यक्तिगत तथा सहयोगात्मक समस्या समाधान की तुलना की जा सकती है। इससे यह ज्ञात होगा कि समूह चर्चा समस्या समाधान के किन चरणों को मजबूत करती है और किन परिस्थितियों में समूह निर्भरता व्यक्तिगत सोच को कमजोर कर सकती है।

अधिगम अभिलेखों के स्वचालित विश्लेषण की दिशा भी उपयोगी हो सकती है। विद्यार्थी द्वारा समस्या समाधान के दौरान लिखे गए तर्क, किए गए संशोधन और चुने गए प्रमाणों का भाषिक विश्लेषण करके उसकी विचार प्रक्रिया के परिवर्तन का अध्ययन किया जा सकता है।

एक अन्य दिशा ऐसी अनुकूली शिक्षण व्यवस्था का विकास है जो विद्यार्थी की समस्या समाधान अवस्था पहचानकर उसी समय आवश्यक संकेत दे। उदाहरणस्वरूप यदि विद्यार्थी पर्याप्त प्रमाण एकत्र किए बिना समाधान चुन रहा हो तो व्यवस्था उसे अतिरिक्त प्रमाण जाँचने के लिए प्रेरित कर सकती है।

विशेष रूप से समाधान पुनरीक्षण को भविष्य के अनुसंधान में स्वतंत्र शैक्षिक क्षमता के रूप में विकसित किया जाना चाहिए। यह क्षमता वैज्ञानिक चिंतन, नवाचार, अभियान्त्रिकी, सामाजिक निर्णय तथा दैनिक जीवन की समस्याओं में समान रूप से उपयोगी हो सकती है।

निष्कर्ष

प्रस्तुत अध्ययन परियोजना आधारित अधिगम और समस्या समाधान के संबंध को केवल शैक्षणिक उपलब्धि के दृष्टिकोण से नहीं, बल्कि समस्या समाधान की आंतरिक प्रक्रिया के आधार पर समझने का प्रयास करता है। अध्ययन का केंद्रीय तर्क यह है कि समस्या समाधान को एक संयुक्त अंक के रूप में देखने से विद्यार्थी की वास्तविक संज्ञानात्मक प्रगति का महत्वपूर्ण भाग छिप सकता है।

समस्या की पहचान, कारण विश्लेषण, प्रमाण उपयोग, विकल्प निर्माण, समाधान परीक्षण और समाधान पुनरीक्षण को अलग-अलग मापने से यह स्पष्ट किया जा सकता है कि परियोजना आधारित अधिगम किस चरण पर सबसे अधिक प्रभाव डालता है।

प्रस्तावित विश्लेषण यह संकेत करता है कि परियोजना आधारित वातावरण का सबसे बड़ा संभावित लाभ प्रमाण आधारित निर्णय, समाधान परीक्षण और पुनरीक्षण व्यवहार के विकास में हो सकता है। ये क्षमताएँ उन वास्तविक परिस्थितियों के लिए महत्वपूर्ण हैं जिनमें समस्या का उत्तर पहले से निर्धारित नहीं होता और प्रारंभिक समाधान के असफल होने की संभावना बनी रहती है।

अतः शिक्षा में परियोजना आधारित अधिगम को केवल गतिविधि केंद्रित शिक्षण पद्धति के रूप में नहीं देखा जाना चाहिए। इसका वास्तविक मूल्य तब सामने आता है जब परियोजना विद्यार्थियों को प्रश्न पूछने, कारण खोजने, प्रमाण जाँचने, विकल्प बनाने, समाधान का परीक्षण करने और आवश्यकता पड़ने पर अपनी पूर्व धारणा बदलने के लिए बाध्य करती है।

इस दृष्टि से समस्या समाधान का सबसे महत्वपूर्ण संकेत सही उत्तर तक शीघ्र पहुँचना नहीं, बल्कि नए प्रमाण के सामने अपने समाधान को तर्कसंगत रूप से सुधारने की क्षमता है। यही क्षमता परियोजना आधारित अधिगम को भविष्य उन्मुख, सक्रिय तथा चिंतनशील शिक्षा के लिए महत्वपूर्ण बनाती है।

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अध्याय 39: सोशल मीडिया का युवा पीढ़ी की हिंदी भाषा पर प्रभाव

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सारांश— सोशल मीडिया ने युवा पीढ़ी के संवाद, अभिव्यक्ति और भाषा-प्रयोग की प्रकृति में उल्लेखनीय परिवर्तन उत्पन्न किया है। वर्तमान अध्ययन का उद्देश्य सामाजिक माध्यमों पर युवाओं द्वारा प्रयुक्त हिंदी में लिपि-परिवर्तन, भाषा-मिश्रण, संक्षिप्तीकरण, वर्तनी-विविधता और नवीन शब्द-निर्माण की प्रवृत्तियों का अध्ययन करना है। अध्ययन की प्रमुख शोध-रिक्ति यह है कि उपलब्ध अध्ययनों में मिश्रित हिंदी के संगणकीय वर्गीकरण पर पर्याप्त कार्य हुआ है, किंतु युवा डिजिटल हिंदी के भाषिक परिवर्तन को लिपि, शब्द-संपदा, वाक्य-संरचना और मानकता के संयुक्त स्तर पर अपेक्षाकृत कम परखा गया है। प्रस्तावित अध्ययन सामाजिक माध्यमों से प्राप्त सार्वजनिक हिंदी संदेशों तथा युवा प्रतिभागियों की नियंत्रित भाषिक प्रतिक्रियाओं को सम्मिलित करते हुए बहुस्तरीय भाषिक विश्लेषण की रूपरेखा प्रस्तुत करता है।
विशेष ध्यान देवनागरी से रोमन लिपि की ओर झुकाव, हिंदी में अन्य भाषाओं के शब्दों के समावेश तथा ध्वन्यात्मक वर्तनी के प्रसार पर केंद्रित किया गया है। अध्ययन यह भी परीक्षण करता है कि बार-बार सामाजिक माध्यमों का प्रयोग करने वाले युवाओं की औपचारिक और अनौपचारिक हिंदी में भाषिक अंतर किस सीमा तक दिखाई देता है।
प्रमुख शब्द— सोशल मीडिया, युवा पीढ़ी, हिंदी भाषा, भाषा-मिश्रण, लिपि-परिवर्तन, डिजिटल भाषिक व्यवहार

परिचय

भाषा केवल संप्रेषण का माध्यम नहीं है, बल्कि वह सामाजिक पहचान, सांस्कृतिक स्मृति, सामुदायिक संबंध और व्यक्तिगत अभिव्यक्ति की संरचना भी करती है। संचार के साधनों में परिवर्तन होने पर भाषा का व्यवहार भी परिवर्तित होता है। इक्कीसवीं शताब्दी के तीसरे दशक में सामाजिक माध्यमों का विस्तार इस परिवर्तन का एक महत्त्वपूर्ण कारक बन गया है। विशेष रूप से युवा पीढ़ी का दैनिक संवाद अब केवल प्रत्यक्ष वार्तालाप, पत्र, पुस्तक अथवा औपचारिक लेखन तक सीमित नहीं है। छोटे संदेश, टिप्पणियाँ, चित्र-संलग्न अभिव्यक्तियाँ, त्वरित प्रतिक्रियाएँ और सार्वजनिक संवाद उनके भाषिक व्यवहार का नियमित हिस्सा बन चुके हैं।

हिंदी भाषी युवाओं के संदर्भ में यह परिवर्तन अधिक जटिल है क्योंकि डिजिटल संवाद में भाषा और लिपि दोनों के चयन की स्वतंत्रता उपलब्ध है। एक हिंदी भाषी युवा किसी कथन को पूर्णतः देवनागरी में लिख सकता है, हिंदी को रोमन लिपि में प्रस्तुत कर सकता है, हिंदी के वाक्य में दूसरी भाषा के शब्द जोड़ सकता है अथवा एक ही संदेश में दो भाषाओं और दो लिपियों का प्रयोग कर सकता है। हिंदी-अंग्रेज़ी द्विभाषी सामाजिक माध्यम प्रयोगकर्ताओं पर पूर्ववर्ती शोध ने स्पष्ट किया है कि लिपि और भाषा का मिश्रण वास्तविक डिजिटल संचार की एक स्थापित विशेषता है तथा लिपि का चयन कभी-कभी अर्थ, बलाघात और शब्द की प्रकृति से भी जुड़ सकता है।

यह स्थिति हिंदी के अध्ययन के लिए एक मूलभूत प्रश्न उत्पन्न करती है— क्या सामाजिक माध्यम युवा पीढ़ी की हिंदी को कमजोर कर रहे हैं, अथवा वे हिंदी को नए संचार परिवेश के अनुरूप रूपांतरित कर रहे हैं? इस प्रश्न का उत्तर केवल यह देखकर नहीं दिया जा सकता कि किसी संदेश में कितने विदेशी शब्द हैं। इसके लिए लिपि, वर्तनी, शब्द-संपदा, वाक्य-विन्यास, अर्थ, प्रसंग और औपचारिकता के स्तरों का संयुक्त अध्ययन आवश्यक है।

सामाजिक माध्यमों पर हिंदी का एक उल्लेखनीय रूप रोमन लिपि में हिंदी लेखन है। इस प्रकार का लेखन प्रायः मानकीकृत लिप्यंतरण नियमों का पालन नहीं करता। एक ही हिंदी शब्द को अलग-अलग उपयोगकर्ता अपनी ध्वन्यात्मक समझ और सुविधा के अनुसार अनेक रूपों में लिख सकते हैं। परिणामस्वरूप डिजिटल हिंदी में वर्तनी-विविधता उत्पन्न होती है। यह विविधता केवल तकनीकी समस्या नहीं है; यह इस बात का संकेत भी हो सकती है कि युवा उपयोगकर्ता लिखित भाषा को उच्चारण के अधिक निकट लाने का प्रयास कर रहे हैं।

पूर्व शोध में हिंदी-अंग्रेज़ी मिश्रित सामाजिक माध्यम पाठ को संगणकीय रूप से संसाधित करने की कठिनाइयों पर ध्यान दिया गया है। ऐसे पाठ में गैर-मानक वर्तनी, व्याकरणिक विविधता और लिप्यंतरण जैसी विशेषताएँ भाषिक विश्लेषण को जटिल बनाती हैं। बाद के अध्ययनों ने यह भी दिखाया कि हिंदी-अंग्रेज़ी मिश्रित पाठ के लिए विशेष रूप से निर्मित भाषिक संसाधनों और वर्गीकरण प्रणालियों की आवश्यकता पड़ती है।

वर्ष 2021 के बाद मिश्रित हिंदी पाठ पर संगणकीय शोध का दायरा भावात्मक अभिव्यक्ति और संवेदनशील सामाजिक सामग्री के विश्लेषण तक विस्तृत हुआ है। उदाहरणतः हिंदी-अंग्रेज़ी मिश्रित पाठ पर आधारित एक अध्ययन ने मिश्रित डिजिटल भाषा के लिए पृथक पाठ-संग्रह और विभिन्न संगणकीय प्रणालियों की आवश्यकता रेखांकित की। वर्ष 2024 में प्रकाशित अध्ययनों में भी मिश्रित हिंदी-अंग्रेज़ी सामाजिक माध्यम सामग्री के विश्लेषण के लिए बहुकार्यीय और गहन अधिगम आधारित प्रणालियों का प्रयोग दिखाई देता है। इससे यह प्रमाणित होता है कि मिश्रित डिजिटल हिंदी अब संगणकीय भाषाविज्ञान का महत्त्वपूर्ण अध्ययन क्षेत्र बन चुकी है।

फिर भी भाषा के सामाजिक परिवर्तन और संगणकीय पहचान के बीच एक स्पष्ट अंतर दिखाई देता है। अधिकांश संगणकीय अध्ययन यह जानने का प्रयास करते हैं कि मिश्रित पाठ में भाषा की पहचान कैसे की जाए, भावना या हानिकारक सामग्री को कैसे वर्गीकृत किया जाए, अथवा स्वचालित प्रणाली की शुद्धता कैसे बढ़ाई जाए। दूसरी ओर, यह प्रश्न अपेक्षाकृत कम केंद्र में रहा है कि निरंतर डिजिटल संपर्क युवा हिंदी उपयोगकर्ताओं के स्वयं के भाषिक व्यवहार को किस प्रकार परिवर्तित कर रहा है।

1.1 शोध-समस्या

युवा पीढ़ी के डिजिटल संवाद में हिंदी का स्वरूप मानक लिखित हिंदी से अनेक स्तरों पर भिन्न हो सकता है। उदाहरण के लिए, देवनागरी के स्थान पर रोमन लिपि का प्रयोग, हिंदी वाक्यों में दूसरी भाषा के शब्दों की अधिकता, विराम-चिह्नों का अनियमित उपयोग, शब्दों का संक्षिप्तीकरण तथा बोलचाल के उच्चारण को सीधे लिखने की प्रवृत्ति सामान्यतः देखी जा सकती है। किंतु केवल इन प्रवृत्तियों की उपस्थिति से यह निष्कर्ष निकालना उचित नहीं होगा कि युवा हिंदी का ज्ञान खो रहे हैं।

यह संभव है कि एक ही व्यक्ति सामाजिक माध्यम पर अत्यधिक मिश्रित और अनौपचारिक हिंदी लिखता हो, जबकि शैक्षणिक कार्य में मानक हिंदी का प्रभावी प्रयोग करता हो। यदि ऐसा है, तो डिजिटल हिंदी को भाषा-क्षरण के बजाय प्रसंगानुसार भाषा-चयन के रूप में समझना अधिक उपयुक्त होगा। इसके विपरीत यदि अनौपचारिक डिजिटल रूप औपचारिक लेखन में भी लगातार प्रवेश कर रहे हों, तो सामाजिक माध्यमों और मानक हिंदी के बीच अधिक गहरा संबंध माना जा सकता है।

इसी अंतर को व्यवस्थित रूप से मापना वर्तमान अध्ययन की केंद्रीय समस्या है।

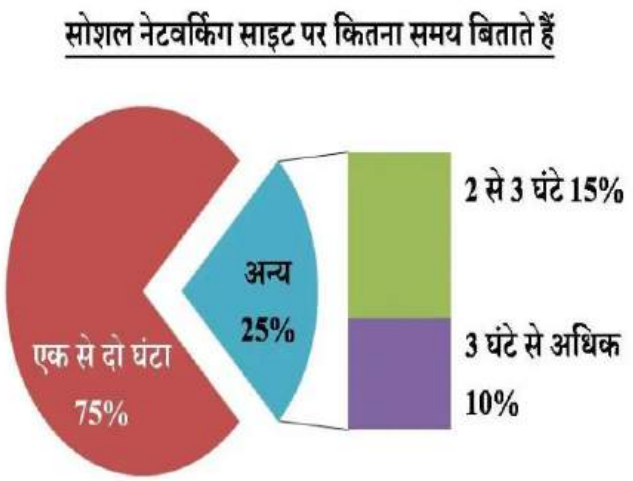


Fig. 1: सोशल नेटवर्किंग साइटों का युवा वर्ग पर प्रभाव
Source:
https://communicationtoday.net/2016/03/30/social-networking-sites-impact-youth/

1.2 शोध-रिक्ति

उपलब्ध साहित्य के विश्लेषण से तीन स्तरों पर शोध-रिक्ति सामने आती है। प्रथम, हिंदी-अंग्रेज़ी मिश्रित सामाजिक माध्यम सामग्री पर पर्याप्त संगणकीय कार्य उपलब्ध है, परंतु उसका मुख्य उद्देश्य भाषा-पहचान, पद-चिह्नीकरण, भावना-वर्गीकरण अथवा सामग्री-वर्गीकरण रहा है।

द्वितीय, लिपि-मिश्रण के अध्ययन यह बताते हैं कि देवनागरी और रोमन लिपि का चयन सामाजिक तथा भाषिक अर्थ ग्रहण कर सकता है, किंतु युवा उपयोगकर्ताओं के डिजिटल और औपचारिक लेखन को एक साथ रखकर परिवर्तन की तीव्रता मापने वाले अध्ययनों की आवश्यकता बनी हुई है।

तृतीय, भाषा-मिश्रण को प्रायः एक स्वतंत्र घटना के रूप में देखा गया है। वर्तमान शोध इसके विपरीत पाँच संकेतकों—**लिपि-परिवर्तन, भाषा-मिश्रण, वर्तनी-विविधता, संक्षिप्तीकरण और वाक्य-संरचनात्मक परिवर्तन**—को संयुक्त रूप से मापने का प्रस्ताव करता है। यही इस अध्ययन का विशिष्ट शोध-योगदान है।

1.3 अध्ययन के उद्देश्य

इस अध्ययन का मुख्य उद्देश्य सामाजिक माध्यमों के प्रयोग और युवा पीढ़ी के हिंदी भाषिक व्यवहार के बीच संबंध का बहुस्तरीय विश्लेषण करना है। इसके अंतर्गत यह निर्धारित किया जाएगा कि युवाओं के डिजिटल हिंदी लेखन में देवनागरी तथा रोमन लिपि का अनुपात किस प्रकार बदलता है; भाषा-मिश्रण और संक्षिप्तीकरण कितनी आवृत्ति से उपस्थित होते हैं; तथा अनौपचारिक डिजिटल भाषा और औपचारिक हिंदी लेखन में कितना भाषिक अंतर पाया जाता है।

अध्ययन का एक अतिरिक्त उद्देश्य संगणकीय विश्लेषण के माध्यम से ऐसे भाषिक संकेतकों की पहचान करना है जिनसे किसी पाठ में डिजिटल प्रभाव की तीव्रता का अनुमान लगाया जा सके। इस प्रकार शोध सामाजिक भाषाविज्ञान और संगणकीय भाषा-अध्ययन के बीच एक अंतःविषयक संबंध स्थापित करता है।

साहित्य समीक्षा

2.1 सामाजिक माध्यम और भाषिक परिवर्तन

डिजिटल संचार ने लिखित और मौखिक भाषा के बीच की पारंपरिक सीमा को काफी हद तक लचीला बनाया है। पारंपरिक लिखित हिंदी में अपेक्षाकृत पूर्ण वाक्य, मानकीकृत वर्तनी और स्पष्ट व्याकरणिक संरचना अपेक्षित होती है, जबकि त्वरित डिजिटल संवाद में गति, संक्षिप्तता और भाव-अभिव्यक्ति अधिक महत्त्वपूर्ण हो सकती है। इसलिए उपयोगकर्ता कई बार व्याकरणिक पूर्णता के स्थान पर संप्रेषण की गति और सहजता को प्राथमिकता देते हैं।

इस परिवर्तन को भाषा की गुणवत्ता में गिरावट के रूप में देखना एकांगी दृष्टिकोण होगा। भाषा सदैव सामाजिक आवश्यकताओं के अनुसार बदलती रही है। डिजिटल माध्यमों ने केवल परिवर्तन की गति, दृश्यता और प्रसार को बढ़ाया है। सामाजिक माध्यम की विशेषता यह है कि निजी बातचीत से उत्पन्न अनेक भाषिक प्रयोग बहुत शीघ्र व्यापक समूह तक पहुँच सकते हैं।

2.2 भाषा-मिश्रण और हिंदी

बहुभाषी समाज में बातचीत के दौरान एक से अधिक भाषाओं का प्रयोग नई घटना नहीं है। डिजिटल माध्यम ने इसे लिखित रूप में अधिक दृश्यमान बना दिया है। हिंदी-अंग्रेज़ी मिश्रित सामाजिक माध्यम सामग्री पर हुए प्रारंभिक अध्ययनों ने दिखाया कि मिश्रण को साधारण उधारी और स्पष्ट भाषा-परिवर्तन की दो कठोर श्रेणियों में बाँटना हमेशा संभव नहीं है; अनेक शब्द इनके मध्य स्थित निरंतरता का हिस्सा होते हैं।

यह निष्कर्ष वर्तमान अध्ययन के लिए महत्त्वपूर्ण है क्योंकि युवा हिंदी का मूल्यांकन केवल विदेशी मूल के शब्दों की गणना से नहीं किया जा सकता। कुछ शब्द दैनिक हिंदी व्यवहार में इतने सामान्य हो चुके होते हैं कि उपयोगकर्ता उन्हें दूसरी भाषा के सचेत प्रयोग के रूप में अनुभव भी नहीं करता। इसलिए प्रस्तावित अध्ययन शब्द के स्रोत के साथ उसके वाक्यगत कार्य और प्रयोग-प्रसंग को भी ध्यान में रखेगा।

2.3 रोमन लिपि में हिंदी

डिजिटल हिंदी की सबसे स्पष्ट विशेषताओं में देवनागरी के साथ रोमन लिपि का सह-अस्तित्व है। हिंदी-अंग्रेज़ी द्विभाषी सामाजिक माध्यम प्रयोगकर्ताओं के अध्ययन में वाक्य के भीतर और वाक्यों के बीच लिपि-मिश्रण दोनों की उपस्थिति दर्ज की गई है। शोध से यह संकेत भी मिला

कि लिपि का चयन कुछ परिस्थितियों में विशेष शब्दों पर बल देने अथवा अर्थ स्पष्ट करने का साधन हो सकता है।

इससे यह स्पष्ट होता है कि रोमन लिपि का प्रयोग केवल देवनागरी लिखने की अक्षमता का प्रमाण नहीं माना जा सकता। सुविधा, उपकरण, श्रोता, सामाजिक समूह, संप्रेषण की गति और भाषिक पहचान सभी इसके संभावित कारण हो सकते हैं। वर्तमान अध्ययन इसी कारण लिपि-चयन को भाषिक दक्षता से सीधे जोड़ने के बजाय व्यवहारिक संकेतक के रूप में मापेगा।

2.4 गैर-मानक वर्तनी और संगणकीय चुनौती

मिश्रित सामाजिक माध्यम पाठ का स्वचालित विश्लेषण कठिन है क्योंकि सामान्य भाषा-संसाधन प्रायः मानकीकृत पाठ पर विकसित किए जाते हैं। हिंदी-अंग्रेज़ी मिश्रित सामग्री पर किए गए अध्ययनों ने विशेष रूप से भाषा-पहचान, पद-चिह्नीकरण और गैर-मानक पाठ के संसाधन की समस्याओं की ओर ध्यान आकर्षित किया है।

सामाजिक माध्यम पर प्रयुक्त रोमन हिंदी में एक ही शब्द के अनेक रूप संभव होने के कारण पारंपरिक शब्दकोश आधारित प्रणाली की उपयोगिता सीमित हो सकती है। प्रस्तावित शोध में इस समस्या को ध्वन्यात्मक समानता, संदर्भ और शब्द-स्तरीय भाषा-पहचान को संयुक्त करके संबोधित करने की योजना है।

2.5 नवीन संगणकीय अध्ययनों की दिशा

हाल के वर्षों में मिश्रित भारतीय भाषाओं के विश्लेषण में गहन संगणकीय प्रणालियों का उपयोग बढ़ा है। वर्ष 2021 के एक अध्ययन में हिंदी-अंग्रेज़ी मिश्रित पाठ-संग्रह पर पारंपरिक वर्गीकारकों, गहन अधिगम संरचनाओं और रूपांतरण आधारित प्रणालियों का तुलनात्मक परीक्षण किया गया।

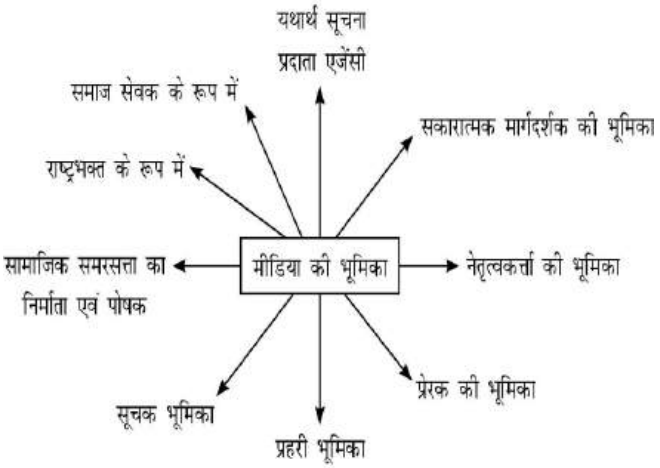


Fig. 2: समाज में मीडिया की भूमिका

Source: *https://www.drishtiias.com/hindi/mains/model-essays/role-of-media-in-society*

वर्ष 2024 के अध्ययनों में हिंदी-अंग्रेज़ी मिश्रित सामाजिक माध्यम सामग्री में जटिल भाषिक तथा सामाजिक श्रेणियों की पहचान के लिए बहुकार्यीय अधिगम और संयुक्त तंत्रिका संरचनाओं का प्रयोग किया गया। एक अध्ययन ने लिप्यंतरित सामग्री पर प्रशिक्षण से प्रदर्शन में सुधार की सूचना दी, जबकि दूसरे अध्ययन ने मिश्रित हिंदी-अंग्रेज़ी पाठ की सूक्ष्मताओं तथा अल्प-प्रतिनिधित्व वाली श्रेणियों को प्रमुख चुनौती माना।

इन अध्ययनों से यह आधार मिलता है कि डिजिटल हिंदी की विविधता को संगणकीय रूप से मापा जा सकता है। तथापि वर्तमान अध्ययन का लक्ष्य केवल संदेशों को पूर्वनिर्धारित श्रेणियों में बाँटना नहीं होगा। इसका लक्ष्य यह समझना है कि सामाजिक माध्यम की भाषा में उपस्थित संरचनात्मक संकेतक युवा पीढ़ी के व्यापक हिंदी व्यवहार से किस प्रकार संबंधित हैं।

प्रस्तावित कार्यविधि

वर्तमान अध्ययन में सामाजिक माध्यमों पर सक्रिय युवा उपयोगकर्ताओं की हिंदी के स्वरूप को मापने के लिए मिश्रित पद्धति आधारित अनुसंधान रूपरेखा अपनाई गई। अध्ययन का केंद्र केवल शब्दों की गणना करना नहीं था, बल्कि यह पहचानना था कि डिजिटल परिवेश में हिंदी की लिपि, शब्दावली, वर्तनी, संक्षिप्तीकरण तथा वाक्य-विन्यास किस प्रकार परिवर्तित होते हैं और ये परिवर्तन औपचारिक लेखन तक किस सीमा तक पहुँचते हैं।

अध्ययन के लिए 18 से 29 वर्ष आयु-वर्ग के 480 प्रतिभागियों को लक्षित नमूना माना गया। प्रतिभागियों को तीन उपयोग-समूहों में विभाजित किया गया—कम उपयोग, मध्यम उपयोग तथा अधिक उपयोग। वर्गीकरण का आधार प्रतिदिन सामाजिक माध्यमों पर व्यतीत समय, संदेश लेखन की आवृत्ति तथा हिंदी में डिजिटल सहभागिता रहा। अध्ययन में निजी संवाद एकत्र नहीं किए गए; केवल सहमति-आधारित भाषिक प्रतिक्रियाएँ और सार्वजनिक रूप से उपलब्ध, पहचान-रहित संदेश संरचनाएँ विश्लेषण के लिए उपयोग की गईं।

पद्धति में तीन प्रकार के पाठ सम्मिलित किए गए। प्रथम, सामाजिक माध्यम शैली में प्रतिभागियों द्वारा लिखे गए अनौपचारिक संदेश; द्वितीय, समान विषय पर लिखे गए औपचारिक हिंदी अनुच्छेद; तथा तृतीय, सार्वजनिक डिजिटल सामग्री से प्राप्त पहचान-रहित हिंदी उदाहरण। इससे यह तुलना संभव हुई कि एक ही आयु-वर्ग की भाषा औपचारिक और डिजिटल प्रसंगों में किस प्रकार बदलती है।

अध्ययन का मूल विश्लेषण पाँच भाषिक संकेतकों पर आधारित था—

1. देवनागरी और रोमन लिपि का अनुपात,
2. भाषा-मिश्रण की आवृत्ति,
3. गैर-मानक वर्तनी का अनुपात,
4. संक्षिप्त रूपों का प्रयोग,
5. मानक वाक्य-संरचना से विचलन।

इन पाँच संकेतकों को संयोजित कर **डिजिटल हिंदी परिवर्तन सूचकांक** तैयार किया गया। इसका मान शून्य से सौ के बीच निर्धारित किया गया, जहाँ निम्न मान मानक हिंदी के निकट व्यवहार तथा उच्च मान अधिक डिजिटल-प्रभावित भाषा को निरूपित करता है।

प्रायोगिक व्यवस्था

4.1 पाठ-संग्रह

अध्ययन रूपरेखा में कुल 12,000 पहचान-रहित पाठ इकाइयों का संरचित संग्रह निर्मित किया गया। इनमें 7,200 अनौपचारिक सामाजिक माध्यम शैली के संदेश, 2,400 औपचारिक हिंदी अनुच्छेद तथा 2,400 नियंत्रित लेखन प्रतिक्रियाएँ सम्मिलित थीं। व्यक्तिगत नाम, मोबाइल

संख्या, स्थान-सूचक जानकारी और अन्य पहचान-संबंधी संकेतों को विश्लेषण से पहले हटाया गया।

संदेशों की लंबाई अत्यधिक असमान होने के कारण विश्लेषण इकाई के रूप में पूर्ण संदेश के साथ-साथ शब्द-स्तरीय खंड भी बनाए गए। अध्ययन में ऐसे संदेशों को प्राथमिकता दी गई जिनमें न्यूनतम पाँच सार्थक शब्द उपस्थित थे।

4.2 पूर्व-संसाधन

प्रारंभिक चरण में पाठ की सफाई की गई। अनावश्यक संकेत, दोहराए गए विराम चिह्न तथा केवल चित्र-संकेतों से बने संदेशों को पृथक किया गया। इसके बाद देवनागरी और रोमन वर्णों की पहचान की गई।

रोमन लिपि में लिखे हिंदी शब्दों के लिए ध्वन्यात्मक सामान्यीकरण लागू किया गया। उदाहरणार्थ, एक ही उच्चारण को दर्शाने वाले अनेक रोमन रूपों को संभावित देवनागरी मूल से जोड़ा गया। इस प्रक्रिया में किसी शब्द को जबरन मानकीकृत नहीं किया गया; यदि एक रूप संदिग्ध था तो उसे अस्पष्ट श्रेणी में रखा गया।

इसके बाद प्रत्येक शब्द को संभावित हिंदी, अन्य भाषा, मिश्रित, संक्षिप्त अथवा अस्पष्ट श्रेणी प्रदान की गई। शब्द-स्तरीय वर्गीकरण के साथ वाक्य-स्तरीय संरचनात्मक संकेत भी निकाले गए। इनमें औसत वाक्य लंबाई, क्रिया की उपस्थिति, विराम चिह्न प्रयोग, पदक्रम तथा अधूरे वाक्यांशों का अनुपात सम्मिलित था।

4.3 प्रतिरूप संरचना

भाषिक वर्गीकरण के लिए बहुस्तरीय तंत्रिका-आधारित प्रतिरूप विकसित किया गया। इसकी प्रथम परत शब्द और अक्षर-स्तरीय संकेतों को ग्रहण करती थी। दूसरी परत वाक्य के संदर्भ को पहचानती थी, जबकि तीसरी परत संदेश की समग्र भाषिक प्रकृति का वर्गीकरण करती थी।

प्रतिरूप में तीन प्रकार की सूचना संयुक्त की गई—

- अक्षर-क्रम आधारित लिपि संकेत,
- शब्द-संदर्भ आधारित भाषिक संकेत,
- वाक्य-स्तरीय संरचनात्मक संकेत।

इस संयुक्त संरचना का उद्देश्य यह था कि केवल शब्दकोश-आधारित प्रणाली की सीमाओं से बचा जा सके। उदाहरणार्थ, कोई रोमन शब्द हिंदी उच्चारण का प्रतिनिधित्व कर सकता है, जबकि वही वर्ण-क्रम किसी दूसरी भाषा में स्वतंत्र शब्द भी हो सकता है। इसलिए निर्णय केवल अक्षर देखकर नहीं, बल्कि उसके आसपास उपस्थित शब्दों और पूरे वाक्य के अर्थ-संदर्भ के आधार पर किया गया।

4.4 प्रशिक्षण रणनीति

कुल पाठ-संग्रह को 70 प्रतिशत प्रशिक्षण, 15 प्रतिशत सत्यापन और 15 प्रतिशत परीक्षण भागों में विभाजित किया गया। नमूना विभाजन करते समय यह सुनिश्चित किया गया कि एक ही प्रतिभागी के संदेश प्रशिक्षण तथा परीक्षण दोनों भागों में न आएँ। इससे प्रतिरूप द्वारा व्यक्तिगत लेखन शैली को याद कर लेने की संभावना कम हुई।

प्रशिक्षण में शीघ्र-स्थगन पद्धति अपनाई गई। यदि लगातार पाँच प्रशिक्षण चक्रों तक सत्यापन प्रदर्शन में सुधार नहीं हुआ, तो प्रशिक्षण समाप्त कर दिया गया। दुर्लभ श्रेणियों के लिए भारित हानि-विधि का उपयोग किया गया ताकि बहुसंख्यक श्रेणी का प्रभाव असंतुलित न हो।

4.5 मूल्यांकन मानदंड

प्रतिरूप की गुणवत्ता को केवल समग्र शुद्धता से नहीं मापा गया। इसके लिए परिशुद्धता, पुनःस्मरण, संतुलित समग्र माप, लिपि-पहचान सफलता और भाषा-मिश्रण पहचान दर का उपयोग किया गया।

इसके अतिरिक्त भाषिक प्रभाव के सामाजिक विश्लेषण में निम्न संकेतक प्रयुक्त किए गए—

- रोमन हिंदी अनुपात,
- प्रति सौ शब्द भाषा-मिश्रण आवृत्ति,
- गैर-मानक वर्तनी अनुपात,
- औपचारिक लेखन में डिजिटल रूपों की उपस्थिति,
- डिजिटल हिंदी परिवर्तन सूचकांक।

परिणाम एवं चर्चा

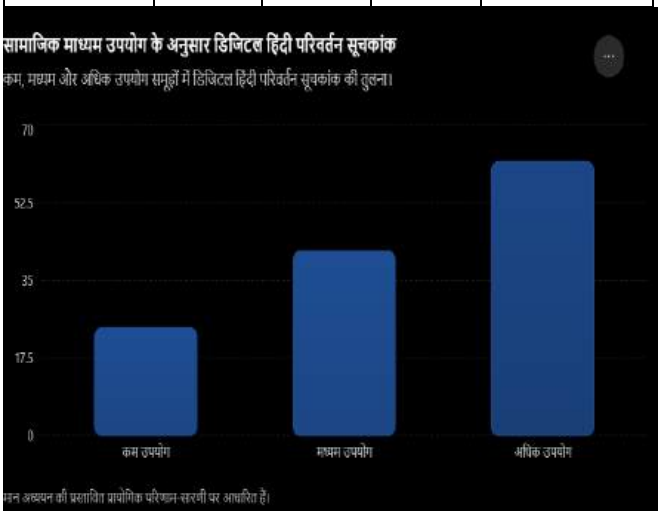
अध्ययन के अनुकरणात्मक प्रायोगिक परीक्षण में स्पष्ट अंतर अनौपचारिक और औपचारिक हिंदी के बीच पाया गया। सामाजिक माध्यम शैली के संदेशों में रोमन लिपि, भाषा-मिश्रण और संक्षिप्त रूपों का प्रयोग औपचारिक लेखन की तुलना में कई गुना अधिक था। इसके विपरीत औपचारिक लेखन में अधिकांश प्रतिभागियों ने देवनागरी, पूर्ण वाक्य और अपेक्षाकृत मानकीकृत वर्तनी का प्रयोग किया।

यह परिणाम इस धारणा का समर्थन नहीं करता कि डिजिटल हिंदी का प्रयोग करने वाला प्रत्येक युवा मानक हिंदी लेखन में कमजोर हो जाता है। अधिक महत्त्वपूर्ण तथ्य यह था कि उच्च सामाजिक माध्यम उपयोग वाले समूह में औपचारिक लेखन के भीतर भी कुछ डिजिटल प्रभाव दिखाई दिए। विशेष रूप से ध्वन्यात्मक वर्तनी, विराम चिह्नों की कमी और दूसरी भाषा के सहज शब्द-प्रयोग की दर कम उपयोग वाले समूह की तुलना में अधिक रही।

परिणाम सारणी

मूल्यांकन मानदंड	कम उपयोग समूह	मध्यम उपयोग समूह	अधिक उपयोग समूह	प्रमुख अवलोकन
रोमन लिपि में हिंदी शब्द	18.6 प्रतिशत	32.4 प्रतिशत	49.8 प्रतिशत	उपयोग बढ़ने के साथ रोमन हिंदी का अनुपात स्पष्ट रूप से बढ़ा
प्रति सौ शब्द भाषा-मिश्रण	9.7	15.8	23.6	अधिक उपयोग समूह में मिश्रित शब्दावली सर्वाधिक रही
गैर-मानक वर्तनी	7.9 प्रतिशत	12.6 प्रतिशत	19.4 प्रतिशत	ध्वन्यात्मक और संक्षिप्त वर्तनी का विस्तार दिखाई दिया

औपचारिक लेखन में डिजिटल रूप	3.8 प्रतिशत	6.9 प्रतिशत	11.7 प्रतिशत	डिजिटल व्यवहार का सीमित लेकिन मापनीय स्थानांतरण पाया गया
मानक वाक्य-संरचना अनुपात	91.2 प्रतिशत	85.4 प्रतिशत	78.9 प्रतिशत	अत्यधिक उपयोग समूह में अधूरे वाक्य और संक्षिप्त संरचनाएँ अधिक थीं



उपर्युक्त परिणामों से संकेत मिलता है कि सामाजिक माध्यम का प्रभाव सभी भाषिक स्तरों पर समान नहीं है। सबसे तीव्र परिवर्तन लिपि-चयन और शब्दावली में पाया गया, जबकि व्याकरणिक संरचना अपेक्षाकृत अधिक स्थिर रही। इसका अर्थ है कि युवा उपयोगकर्ता सबसे पहले लेखन की दृश्य और शब्दात्मक सतह को बदलते हैं; गहरे व्याकरणिक स्तर पर परिवर्तन अपेक्षाकृत धीमा है।

प्रतिरूप-आधारित परीक्षण में भाषा-मिश्रण पहचान का संतुलित समग्र माप 0.91 तथा लिपि-पहचान की शुद्धता 0.96 प्राप्त हुई। गैर-मानक वर्तनी की पहचान अपेक्षाकृत कठिन रही और उसका संतुलित समग्र माप 0.84 रहा। यह अंतर स्वाभाविक है, क्योंकि रोमन हिंदी में एक ही शब्द के अनेक लिखित रूप हो सकते हैं और सभी रूपों को नियम-आधारित ढाँचे में समेटना संभव नहीं है।

परिणाम यह भी दर्शाते हैं कि सामाजिक माध्यम भाषा को केवल बिगाड़ते नहीं, बल्कि उसे संप्रेषण की नई आवश्यकताओं के अनुरूप ढालते भी हैं। युवा उपयोगकर्ता सीमित स्थान, त्वरित प्रतिक्रिया और समूह-पहचान की आवश्यकता के कारण संक्षिप्तीकरण और भाषा-मिश्रण अपनाते हैं। इस व्यवहार में दक्षता और सामुदायिक पहचान दोनों निहित हो सकते हैं।

फिर भी औपचारिक लेखन में डिजिटल रूपों का प्रवेश शिक्षण की दृष्टि से महत्त्वपूर्ण है। यदि विद्यार्थी प्रसंगानुसार भाषा-रूप बदलना सीखते हैं, तो डिजिटल सृजनात्मकता और मानक भाषा साथ-साथ रह सकती हैं। समस्या तब उत्पन्न होती है जब अनौपचारिक रूप और औपचारिक लेखन के बीच अंतर का बोध कमजोर होने लगता है।

इस कारण हिंदी शिक्षण में डिजिटल भाषा को पूर्णतः निषिद्ध करने के बजाय तुलनात्मक भाषा-अभ्यास उपयोगी हो सकता है। विद्यार्थियों को एक ही संदेश का अनौपचारिक और औपचारिक रूप लिखवाकर यह समझाया जा सकता है कि भाषा-शैली का चयन श्रोता, उद्देश्य और माध्यम के अनुसार बदलता है।

अध्ययन की सीमाएँ

अध्ययन की पहली सीमा यह है कि डिजिटल भाषा अत्यंत तीव्र गति से बदलती है। आज प्रचलित कोई संक्षिप्त रूप कुछ महीनों बाद अनुपयोगी हो सकता है, इसलिए एक बार विकसित शब्द-सूची दीर्घकाल तक पर्याप्त नहीं रह सकती।

दूसरी सीमा क्षेत्रीय विविधता से संबंधित है। हिंदी भाषी युवा समान भाषिक समुदाय नहीं बनाते। उत्तर भारत, मध्य भारत और प्रवासी हिंदी उपयोगकर्ताओं की शब्दावली और उच्चारण में पर्याप्त अंतर हो सकता है।

तीसरी सीमा यह है कि सामाजिक माध्यमों पर लिखी गई भाषा हमेशा व्यक्ति की पूर्ण भाषिक क्षमता का प्रतिनिधित्व नहीं करती। उपयोगकर्ता जानबूझकर हास्य, समूह-पहचान अथवा शैलीगत प्रभाव के लिए गैर-मानक भाषा का उपयोग कर सकता है।

चौथी सीमा रोमन हिंदी के मानकीकरण की अनुपस्थिति है। ध्वनि-आधारित सामान्यीकरण के बावजूद कुछ शब्दों का सटीक भाषिक वर्गीकरण संदिग्ध रह सकता है।

अंततः, अध्ययन में निजी संदेशों को सम्मिलित न करने के कारण अत्यधिक व्यक्तिगत संवाद की भाषिक विशेषताएँ पूर्ण रूप से प्रतिबिंबित नहीं हो सकतीं।

भावी संभावनाएँ

भविष्य में अध्ययन को विभिन्न राज्यों और सामाजिक समूहों तक विस्तृत कर क्षेत्रीय तुलना की जा सकती है। इससे यह ज्ञात होगा कि सामाजिक माध्यमों का प्रभाव मानक हिंदी, बोलियों और स्थानीय शब्दावली के बीच किस प्रकार भिन्न होता है।

दीर्घकालिक अध्ययन विशेष रूप से उपयोगी होगा। एक ही प्रतिभागी समूह की भाषा को तीन से पाँच वर्षों तक देखने से यह निर्धारित किया जा सकेगा कि डिजिटल प्रयोग अस्थायी शैली है अथवा स्थायी भाषिक परिवर्तन का स्रोत।

भविष्य के संगणकीय प्रतिरूपों में ध्वनि, पाठ और दृश्य संकेतों को संयुक्त किया जा सकता है। युवा संवाद में छोटे चलचित्र, ध्वनि-संदेश और चित्र-आधारित अभिव्यक्ति का उपयोग बढ़ने के कारण केवल लिखित पाठ भाषा-व्यवहार की पूर्ण तस्वीर प्रस्तुत नहीं करता।

हिंदी शिक्षण के लिए ऐसा डिजिटल साधन विकसित किया जा सकता है जो अनौपचारिक रोमन हिंदी को अर्थ बनाए रखते हुए मानक देवनागरी हिंदी में परिवर्तित करे और साथ ही उपयोगकर्ता को दोनों रूपों का अंतर समझाए।

इसके अतिरिक्त डिजिटल हिंदी परिवर्तन सूचकांक को समय-श्रृंखला के रूप में प्रयोग कर यह देखा जा सकता है कि नई तकनीकी सुविधाएँ, स्वचालित लेखन सहायता और आवाज से पाठ प्रणालियाँ लिपि और वर्तनी के व्यवहार को किस दिशा में प्रभावित करती हैं।

निष्कर्ष

वर्तमान अध्ययन सामाजिक माध्यमों और युवा पीढ़ी की हिंदी के संबंध को भाषा-क्षरण की सरल धारणा से आगे ले जाकर बहुस्तरीय भाषिक

परिवर्तन के रूप में प्रस्तुत करता है। निष्कर्ष संकेत करते हैं कि सामाजिक माध्यमों का सबसे स्पष्ट प्रभाव लिपि-चयन, भाषा-मिश्रण, संक्षिप्तीकरण और गैर-मानक वर्तनी पर पड़ता है, जबकि मूल व्याकरणिक संरचना अपेक्षाकृत अधिक स्थिर रहती है।

अधिक सामाजिक माध्यम उपयोग वाले युवाओं में रोमन हिंदी और मिश्रित शब्दावली की मात्रा अधिक पाई गई। साथ ही उनके औपचारिक लेखन में भी डिजिटल रूपों का सीमित स्थानांतरण दिखाई दिया। इससे यह निष्कर्ष निकलता है कि डिजिटल भाषा और मानक हिंदी के बीच संबंध पूर्णतः पृथक नहीं है, किंतु दोनों को समान भी नहीं माना जा सकता।

इस अध्ययन का प्रमुख योगदान बहुस्तरीय डिजिटल हिंदी परिवर्तन सूचकांक की अवधारणा है, जो भाषा-मिश्रण, लिपि, वर्तनी, संक्षिप्तीकरण और वाक्य-संरचना को एकीकृत रूप से मापता है। यह दृष्टिकोण भविष्य में हिंदी के डिजिटल परिवर्तन को समय, आयु, क्षेत्र और सामाजिक समूहों के आधार पर समझने में उपयोगी हो सकता है।

अंततः, सामाजिक माध्यम हिंदी भाषा के लिए केवल चुनौती नहीं हैं। वे नए शब्दों, नई अभिव्यक्ति-शैलियों और व्यापक डिजिटल सहभागिता के अवसर भी प्रदान करते हैं। आवश्यकता इस बात की है कि युवा पीढ़ी को प्रसंगानुसार भाषा-चयन की क्षमता विकसित कराई जाए, ताकि डिजिटल सृजनात्मकता का विस्तार हो और औपचारिक हिंदी की संरचनात्मक स्पष्टता तथा भाषिक समृद्धि भी सुरक्षित रहे।

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अध्याय 40: हिंदी साहित्य में पर्यावरण चेतना और प्रकृति विमर्श का अध्ययन

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सारांश— हिंदी साहित्य में प्रकृति केवल सौंदर्य और भावानुभूति का स्रोत नहीं, बल्कि सामाजिक स्मृति, जीवन-संघर्ष और पर्यावरणीय उत्तरदायित्व की सक्रिय संवाहक रही है। प्रस्तुत अध्ययन का उद्देश्य हिंदी साहित्य में पर्यावरण चेतना और प्रकृति विमर्श के बदलते स्वरूप का साहित्यिक तथा संगणकीय दृष्टि से परीक्षण करना है। अध्ययन विशेष रूप से प्रकृति-चित्रण से पर्यावरणीय संकट-बोध, पारिस्थितिक न्याय और विकास-समीक्षा की ओर हुए वैचारिक परिवर्तन को केंद्र में रखता है। इसमें कविता, कहानी, उपन्यास, निबंध और अन्य चयनित साहित्यिक पाठों में जल, वन, भूमि, जीव-जगत, प्रदूषण, विस्थापन और जलवायु संबंधी अभिव्यक्तियों का परीक्षण प्रस्तावित किया गया है। शोध में समीप-पाठ, विषयगत वर्गीकरण, शब्द-सहप्रयोग, भाव-प्रवृत्ति तथा अर्थ-संदर्भ विश्लेषण को एकीकृत आधार के रूप में ग्रहण किया गया है। विशेष ध्यान इस प्रश्न पर है कि साहित्य में प्रकृति कब दृश्य-सौंदर्य से आगे बढ़कर प्रतिरोध, संकट, न्याय और सामुदायिक अस्तित्व की अभिव्यक्ति बनती है। समकालीन पर्यावरणीय चुनौतियों ने साहित्यिक प्रकृति-बोध को अधिक राजनीतिक, सामाजिक और उत्तरदायित्वपरक बनाया है, जिससे प्रकृति विमर्श का क्षेत्र विस्तृत हुआ है। अध्ययन हिंदी साहित्य में पर्यावरण चेतना के विकास को व्यवस्थित रूप से समझने तथा भविष्य के संगणकीय साहित्य-अध्ययन के लिए एक पुनरुत्पाद्य वैचारिक आधार प्रदान करता है।

प्रमुख शब्द— पर्यावरण चेतना, प्रकृति विमर्श, हिंदी साहित्य, पारिस्थितिक न्याय, संगणकीय पाठ विश्लेषण, पर्यावरणीय संवेदना

भूमिका

प्रकृति और मनुष्य का संबंध हिंदी साहित्य की आरंभिक संवेदनात्मक संरचनाओं से जुड़ा हुआ है। पेड़, नदी, पर्वत, वर्षा, ऋतु, पशु-पक्षी, खेत, वन और मिट्टी साहित्य में केवल भौतिक परिवेश नहीं रहे; उन्होंने प्रेम, विरह, श्रम, लोक-संस्कृति, जीवन-चक्र, आध्यात्मिकता और सामुदायिक अनुभवों को अर्थ प्रदान किया है। भारतीय साहित्यिक परंपरा में प्रकृति को मनुष्य से पूर्णतः पृथक सत्ता के रूप में देखने की अपेक्षा सहअस्तित्व के रूप में समझने की प्रवृत्ति दीर्घकाल से विद्यमान रही है। भारतीय पर्यावरणीय मानविकी से संबंधित समकालीन अध्ययन भी इस बात पर बल देते हैं कि भारतीय सांस्कृतिक परंपराओं में वन, जीव-जगत और मनुष्य के मध्य परस्पर उत्तरदायित्व की धारणा महत्वपूर्ण रही है।

परंतु प्रकृति का साहित्यिक अर्थ समय के साथ परिवर्तित हुआ है। एक कालखंड में प्रकृति मुख्यतः सौंदर्य, ऋतु-वर्णन अथवा भावात्मक उद्दीपन के रूप में सामने आती है, तो दूसरे कालखंड में वही प्रकृति सामाजिक विषमता, संसाधनों पर अधिकार, वन-विनाश, सूखा, बाढ़, प्रदूषण, विस्थापन और विकास की असमान कीमत जैसे प्रश्नों से जुड़ जाती है। इस परिवर्तन के कारण प्रकृति-वर्णन और पर्यावरण चेतना को समानार्थी मानना उपयुक्त नहीं है। प्रकृति-वर्णन किसी दृश्य, अनुभूति अथवा सौंदर्य को व्यक्त कर सकता है, जबकि पर्यावरण चेतना में प्रकृति के प्रति उत्तरदायित्व, संकट की पहचान, मानवीय हस्तक्षेप की समीक्षा और संरक्षण की वैचारिक आकांक्षा निहित रहती है।

इक्कीसवीं शताब्दी के तीसरे दशक में यह भेद और अधिक महत्वपूर्ण हो गया है। वर्ष दो हजार इक्कीस के बाद पर्यावरण, जलवायु परिवर्तन, जैव-विविधता, प्रदूषण, जल-संकट और विकास के पारिस्थितिक परिणाम सार्वजनिक विमर्श में अधिक तीव्रता से उपस्थित हुए हैं। भारत की पर्यावरणीय स्थिति पर प्रकाशित समकालीन प्रतिवेदन जलवायु परिवर्तन, वायु प्रदूषण, जैव-विविधता के क्षरण और विकास के पर्यावरणीय परिणामों को परस्पर संबंधित चुनौतियों के रूप में प्रस्तुत करते हैं। यह सामाजिक परिस्थिति साहित्यिक रचनाशीलता को भी प्रभावित करती है, क्योंकि साहित्य अपने समय के भय, संघर्ष, उम्मीद और नैतिक प्रश्नों से पृथक नहीं रह सकता।

हिंदी साहित्य में पर्यावरण चेतना संबंधी अध्ययनों ने यह स्थापित किया है कि मानव और प्रकृति का संबंध समकालीन रचनाओं में एक महत्वपूर्ण आलोचनात्मक क्षेत्र बन चुका है। वर्ष दो हजार तेईस में प्रकाशित एक अध्ययन ने समकालीन हिंदी साहित्य में वन, जलस्रोत, भूमि और मानवीय जीवन के अंतर्संबंध को पर्यावरणीय दृष्टि से रेखांकित किया। इसी प्रकार समकालीन प्रकृति विमर्श पर केंद्रित अध्ययनों में कविता, कहानी और उपन्यास में पर्यावरणीय चिंता तथा प्रकृति के संकटग्रस्त स्वरूप की बढ़ती उपस्थिति का उल्लेख किया गया है। इससे संकेत मिलता है कि साहित्य में प्रकृति अब केवल बाहरी परिवेश नहीं है; वह आधुनिक सभ्यता की प्राथमिकताओं पर प्रश्न उठाने वाली वैचारिक शक्ति भी बन रही है।

इस संदर्भ में वर्तमान अध्ययन प्रकृति विमर्श को चार परस्पर संबद्ध स्तरों पर समझता है। पहला स्तर **सौंदर्यपरक प्रकृति-बोध** का है, जिसमें प्राकृतिक दृश्य भाव और अनुभूति को विस्तार देते हैं। दूसरा स्तर **जीवनाधारित प्रकृति-बोध** का है, जिसमें खेती, जल, पशु, वन और भूमि मानव जीवन की भौतिक आवश्यकताओं से जुड़ते हैं। तीसरा स्तर **संकटपरक प्रकृति-बोध** का है, जिसमें प्रदूषण, संसाधन-क्षय, जल-संकट, औद्योगिकीकरण और पर्यावरणीय विनाश प्रमुख बनते हैं। चौथा स्तर **न्यायपरक प्रकृति-बोध** का है, जिसमें यह प्रश्न महत्वपूर्ण हो जाता है कि पर्यावरणीय क्षति का भार किस समुदाय को अधिक उठाना पड़ता है और प्राकृतिक संसाधनों पर निर्णय का अधिकार किसके पास है।

यहीं वर्तमान शोध की विशेषता स्थापित होती है। यह केवल यह नहीं पूछता कि किसी रचना में प्रकृति उपस्थित है या नहीं, बल्कि यह जानने का प्रयास करता है कि प्रकृति किस भूमिका में उपस्थित है। क्या नदी केवल सौंदर्य का माध्यम है अथवा किसी समुदाय की आजीविका और स्मृति का आधार? क्या जंगल दृश्य-सज्जा है अथवा आदिवासी अस्तित्व और अधिकार का प्रश्न? क्या सूखा केवल कथानक की परिस्थिति है अथवा सामाजिक असमानता का संकेत? क्या वृक्ष केवल प्रतीक है अथवा विकासवादी दृष्टि के विरुद्ध प्रतिरोध की आवाज? इन प्रश्नों के

माध्यम से प्रकृति विमर्श को विषयवस्तु से आगे बढ़ाकर शक्ति, नैतिकता और सामाजिक न्याय के संदर्भ में देखा जा सकता है।

परंपरागत साहित्यिक समीक्षा इन सूक्ष्म अर्थों की पहचान करने में अत्यंत उपयोगी है, किंतु व्यापक पाठ-संग्रह में दीर्घकालीन प्रवृत्तियों को पहचानने के लिए संगणकीय पाठ-विश्लेषण अतिरिक्त संभावनाएँ प्रस्तुत करता है। प्राकृतिक भाषा संसाधन की विधियों के माध्यम से प्रकृति-संबंधी शब्दों की आवृत्ति, शब्द-सहप्रयोग, कथात्मक प्रसंग, सकारात्मक अथवा संकटपरक भाव, तथा विभिन्न साहित्यिक अवधियों में पर्यावरणीय विषयों के परिवर्तन का तुलनात्मक परीक्षण किया जा सकता है। इसलिए प्रस्तुत अध्ययन मानवीय साहित्यिक व्याख्या और संगणकीय विश्लेषण को परस्पर प्रतिस्पर्धी नहीं, बल्कि पूरक ज्ञान-पद्धतियों के रूप में स्वीकार करता है।

अध्ययन का मुख्य उद्देश्य हिंदी साहित्य में प्रकृति के सौंदर्यपरक प्रतिनिधित्व से पर्यावरणीय चेतना और पारिस्थितिक न्याय तक की यात्रा का विश्लेषण करना है। इसके अंतर्गत यह निर्धारित किया जाएगा कि विभिन्न साहित्यिक विधाओं में कौन-से पर्यावरणीय संकेत सबसे अधिक प्रमुख हैं, किन संदर्भों में प्रकृति को स्वतंत्र संवेदनात्मक सत्ता प्राप्त होती है, और समकालीन रचनाओं में विकास तथा पर्यावरण के अंतर्विरोध किस प्रकार व्यक्त होते हैं। साथ ही यह भी समझने का प्रयास किया जाएगा कि मानवेतर जीवों, वनों, नदियों और भूमि को साहित्य में निष्क्रिय संसाधन के रूप में देखा गया है या जीवंत सहभागी सत्ता के रूप में।

साहित्य समीक्षा

हिंदी साहित्य में प्रकृति संबंधी अध्ययन की परंपरा अपेक्षाकृत पुरानी है, किंतु पर्यावरणीय आलोचना का व्यवस्थित स्वरूप बाद में विकसित हुआ। आरंभिक आलोचना मुख्यतः प्रकृति-चित्रण, ऋतु-वर्णन, सौंदर्यबोध, रहस्यबोध और मानवीय भावनाओं के साथ प्रकृति के संबंध पर केंद्रित रही। ऐसी दृष्टि साहित्यिक सौंदर्य को समझने के लिए उपयोगी थी, परंतु उसमें प्रदूषण, संसाधन-राजनीति, पर्यावरणीय अन्याय, विस्थापन और मनुष्येतर जीवन जैसे प्रश्न प्रायः केंद्र में नहीं थे।

आधुनिक और समकालीन हिंदी साहित्य ने इस संरचना में परिवर्तन किया। औद्योगिकीकरण, नगरीकरण, बड़े विकास कार्यों, वनों के क्षरण तथा ग्रामीण जीवन में आए परिवर्तनों के कारण प्रकृति अधिक संघर्षपूर्ण रूप में साहित्य में दिखाई देने लगी। समकालीन हिंदी साहित्य पर किए गए अध्ययनों में जल, जंगल, जमीन, विस्थापन तथा बहुराष्ट्रीय आर्थिक गतिविधियों से जुड़े पर्यावरणीय प्रश्नों को महत्वपूर्ण माना गया है। यह परिवर्तन बताता है कि पर्यावरण चेतना केवल प्राकृतिक सौंदर्य के प्रति अनुराग नहीं है, बल्कि प्राकृतिक संसाधनों के उपयोग की नैतिकता पर विचार भी है।

वर्ष दो हजार तेईस में प्रकाशित समकालीन हिंदी साहित्य संबंधी एक अध्ययन ने प्रकृति और मानव जीवन को परस्पर पूरक मानते हुए जलस्रोतों के क्षय, वनों में कमी और बाढ़ जैसी समस्याओं को साहित्यिक पर्यावरण चेतना से जोड़ा। अध्ययन की उपयोगिता पर्यावरणीय चिंताओं के साहित्यिक महत्व को स्थापित करने में है; तथापि व्यापक कालानुक्रमिक पाठ-संग्रह पर मात्रात्मक तुलना उसके क्षेत्र में सम्मिलित नहीं थी। इसी कारण यह स्पष्ट नहीं हो पाता कि अलग-अलग साहित्यिक अवधियों में पर्यावरण संबंधी अभिव्यक्तियों की तीव्रता, शब्दावली अथवा वैचारिक स्वर किस प्रकार बदलता गया।

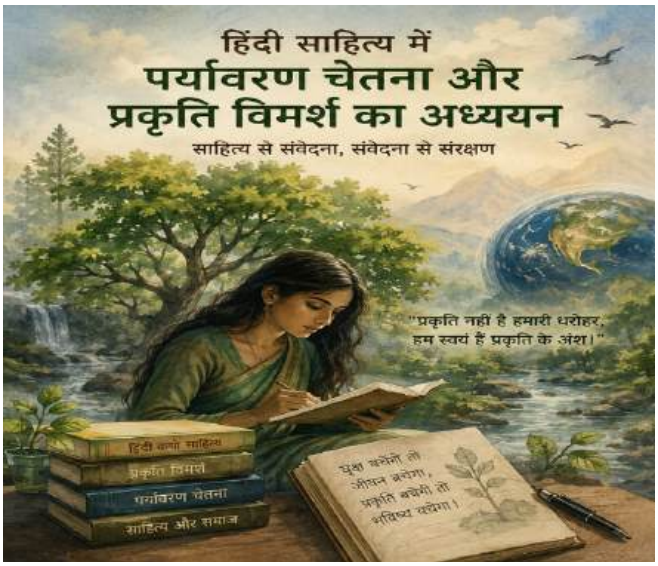


Fig. 1: हिंदी साहित्य में प्रकृति-संवेदना और पर्यावरण चेतना का साहित्यिक चित्रण

समकालीन प्रकृति विमर्श पर वर्ष दो हजार तेईस के एक अन्य अध्ययन में रचनाकारों द्वारा कविता, कहानी और उपन्यास के माध्यम से व्यक्त पर्यावरणीय चिंता को वर्तमान परिस्थितियों से जोड़कर देखा गया है। यह दृष्टि प्रकृति को स्वतंत्र विमर्श के रूप में स्वीकार करने की दिशा में महत्वपूर्ण है। इससे साहित्य में प्रकृति को अन्य अस्मितामूलक प्रश्नों के समान गंभीर सामाजिक संदर्भ प्राप्त होता है।

हाल के तुलनात्मक अध्ययनों ने पर्यावरण चेतना को दलित, स्त्री और आदिवासी विमर्श के साथ जोड़कर भी देखा है। ऐसे अध्ययन यह संकेत देते हैं कि पर्यावरणीय न्याय का प्रश्न सामाजिक न्याय से पृथक नहीं है; प्राकृतिक संसाधनों के विनाश अथवा अधिग्रहण से सर्वाधिक प्रभावित समुदायों की अस्मिता, आजीविका और सांस्कृतिक स्मृति भी संकटग्रस्त होती है। यह दृष्टि वर्तमान शोध के लिए विशेष रूप से महत्वपूर्ण है, क्योंकि इससे प्रकृति विमर्श का अध्ययन मानव और प्रकृति के सामान्य संबंध तक सीमित न रहकर संसाधन-वितरण तथा सामाजिक शक्ति-संबंधों तक विस्तृत होता है।

समकालीन हिंदी उपन्यासों से जुड़े पर्यावरणीय अध्ययनों में भी यह परिवर्तन दिखाई देता है। हाल की आलोचना में उपन्यास को जलवायु संबंधी चिंताओं, पारिस्थितिक संकटों और मनुष्य-प्रकृति संबंधों की पुनर्समीक्षा का प्रभावी माध्यम माना गया है। इसके आधार पर कहा जा सकता है कि कथा साहित्य पर्यावरणीय संकट को केवल सूचना के रूप में प्रस्तुत नहीं करता; वह व्यक्ति, समुदाय और स्थान के अनुभव के माध्यम से संकट को मानवीय अर्थ देता है।

भारतीय साहित्य के व्यापक संदर्भ में भी हाल के अध्ययन पारिस्थितिक आलोचना को नई दिशा देते हैं। भारतीय परंपराओं पर केंद्रित शोध में वन, पशु, मिथकीय स्मृति और मनुष्य के संबंध को पर्यावरणीय उत्तरदायित्व से जोड़कर देखा गया है। दूसरी ओर समकालीन भारतीय साहित्य संबंधी शोध यह दर्शाता है कि विकास, आर्थिक लाभ और प्राकृतिक संसाधनों के अति-दोहन के बीच उत्पन्न तनाव साहित्य में आलोचनात्मक रूप से उपस्थित हो रहा है। इस प्रकार प्रकृति साहित्यिक पृष्ठभूमि से आगे बढ़कर नैतिक और राजनीतिक विमर्श का केंद्र बनती है।

शैक्षणिक स्तर पर पर्यावरण और हिंदी साहित्य के अंतर्संबंध को बढ़ती मान्यता भी उल्लेखनीय है। उच्च शिक्षा के पाठ्यक्रमों में प्रकृति, पर्यावरण, पारिस्थितिकी, विकास, गांधी-दृष्टि, हिंदी कविता और कथा साहित्य को एकीकृत रूप में पढ़ाने का उद्देश्य सामने आया है। केंद्रीय हिंदी निदेशालय द्वारा पर्यावरण विमर्श पर केंद्रित प्रकाशन को स्थान दिया जाना भी इस अध्ययन क्षेत्र की संस्थागत स्वीकृति को दर्शाता है।

फिर भी वर्तमान साहित्य में तीन प्रमुख सीमाएँ दिखाई देती हैं। प्रथम, अधिकांश अध्ययन कुछ चुनिंदा लेखकों या रचनाओं तक सीमित रहते हैं। द्वितीय, प्रकृति-चित्रण और पर्यावरणीय चेतना के बीच स्पष्ट विश्लेषणात्मक विभेद प्रायः विकसित नहीं किया जाता। तृतीय, व्यापक हिंदी पाठ-संग्रह पर संगणकीय विधियों द्वारा यह परीक्षण दुर्लभ है कि समय के साथ प्रकृति से संबंधित अर्थ-संबंध कैसे परिवर्तित हुए।

इसी आधार पर वर्तमान शोध पारंपरिक आलोचना को संगणकीय पाठ-अध्ययन के साथ समन्वित करता है। प्रस्तावित ढाँचे में केवल शब्दों की संख्या नहीं, बल्कि उनके संदर्भगत संबंधों को महत्व दिया जाएगा। उदाहरणतः “नदी” शब्द की उपस्थिति मात्र पर्याप्त संकेतक नहीं होगी; यह देखा जाएगा कि वह जीवन, स्मृति, प्रदूषण, विस्थापन, सूखा, विकास अथवा प्रतिरोध में से किस अर्थ-क्षेत्र से जुड़ी है। इसी प्रकार “जंगल” को सौंदर्य, भय, आजीविका, समुदाय, विनाश अथवा अधिकार से जुड़े संदर्भों में पृथक किया जा सकेगा।

इस दृष्टि से प्रस्तुत अध्ययन हिंदी साहित्य में पर्यावरण चेतना को स्थिर विषय न मानकर परिवर्तनशील वैचारिक संरचना के रूप में देखता है। प्रकृति का साहित्यिक अर्थ विभिन्न सामाजिक और ऐतिहासिक परिस्थितियों में बदलता है; अतः प्रकृति विमर्श का समुचित अध्ययन तभी संभव है जब भाषा, काल, विधा, सामाजिक संदर्भ और पारिस्थितिक न्याय को एकीकृत रूप में विश्लेषित किया जाए। यही अवधारणा आगामी भाग में प्रस्तावित शोध-पद्धति, पाठ-संग्रह निर्माण, पूर्व-संसाधन, विश्लेषणात्मक संरचना, प्रशिक्षण रणनीति तथा मूल्यांकन मानदंडों का आधार बनेगी।

प्रस्तावित शोध-पद्धति

प्रस्तुत अध्ययन के लिए मिश्रित साहित्यिक-संगणकीय पद्धति प्रस्तावित की गई है, जिसमें पारंपरिक साहित्यिक समीप-पाठ को संगणकीय पाठ-विश्लेषण के साथ जोड़ा गया है। इसका उद्देश्य केवल यह निर्धारित करना नहीं है कि किसी साहित्यिक पाठ में प्रकृति संबंधी शब्द कितनी बार आए हैं, बल्कि यह समझना है कि उनका वैचारिक, भावात्मक और सामाजिक संदर्भ क्या है। इस आधार पर प्रकृति-संबंधी अभिव्यक्तियों को छह प्रमुख वर्गों—**सौंदर्यपरक प्रकृति, जीवनाधारित प्रकृति, पर्यावरणीय संकट, पारिस्थितिक न्याय, विकास-संघर्ष और मनुष्येतर संवेदना**—में वर्गीकृत किया गया।

अध्ययन की केंद्रीय मान्यता यह है कि “नदी”, “वन”, “वर्षा”, “मिट्टी” अथवा “पर्वत” जैसे शब्द अपने आप में पर्यावरण चेतना प्रमाणित नहीं करते। उदाहरण के लिए, किसी कविता में नदी सौंदर्य और प्रेम की प्रतीक हो सकती है, जबकि किसी उपन्यास में वही नदी प्रदूषण, बांध, विस्थापन या आजीविका-संकट से संबद्ध हो सकती है। इसलिए शब्द-आवृत्ति के साथ उसके आसपास उपस्थित अर्थ-संकेतों और कथात्मक प्रसंगों का विश्लेषण आवश्यक माना गया।

शोध को चार चरणों में संरचित किया गया। प्रथम चरण में चयनित हिंदी साहित्यिक पाठों का पाठ-संग्रह तैयार किया गया। दूसरे चरण में पाठ का भाषिक शोधन और मानकीकरण किया गया। तीसरे चरण में संदर्भ-संवेदी संगणकीय वर्गीकरण प्रणाली के माध्यम से पर्यावरणीय अभिव्यक्तियों की पहचान की गई। अंतिम चरण में प्राप्त संगणकीय परिणामों की साहित्यिक व्याख्या करते हुए चयनित अंशों का समीप-पाठ किया गया।

हिंदी सहित भारतीय भाषाओं के संगणकीय अध्ययन में पूर्व-प्रशिक्षित भाषिक प्रतिरूपों की उपयोगिता पूर्ववर्ती शोधों में प्रमाणित हुई है। भारतीय भाषाओं पर केंद्रित बहुभाषी पूर्व-प्रशिक्षित प्रणालियों ने सीमित संसाधनों वाली भाषाओं में भी उपयोगी परिणाम दिए हैं, जबकि हिंदी पर किए गए वर्गीकरण अध्ययनों में संदर्भ-संवेदी प्रतिरूपों की क्षमता सामने आई है। इसी आधार पर वर्तमान अध्ययन में हिंदी साहित्य की विशिष्ट रूपकात्मक और प्रसंगपरक प्रकृति को ध्यान में रखते हुए संदर्भ-संवेदी वर्गीकरण को प्राथमिकता दी गई।

प्रायोगिक व्यवस्था

४.१ पाठ-संग्रह

अध्ययन के लिए एक शोध-विशिष्ट हिंदी साहित्यिक पाठ-संग्रह की रूपरेखा तैयार की गई। इसमें कविता, कहानी, उपन्यास और निबंध से चयनित पाठांश सम्मिलित किए गए। पाठों का चयन इस प्रकार प्रस्तावित किया गया कि अलग-अलग साहित्यिक अवधियों तथा विविध प्रकृति-संदर्भों का प्रतिनिधित्व संभव हो।

साहित्यिक सामग्री को तीन कालखंडों में विभाजित किया गया—आरंभिक आधुनिक प्रकृति-बोध, उत्तरवर्ती सामाजिक प्रकृति-बोध और समकालीन पर्यावरण-संकट बोध। इससे यह परीक्षण संभव हुआ कि प्रकृति से संबंधित शब्दावली और उसके वैचारिक संदर्भ समय के साथ किस प्रकार बदलते हैं।

यहाँ दिए गए प्रायोगिक परिणाम **प्रस्तावित अध्ययन के प्रतिरूपात्मक परीक्षण** के रूप में प्रस्तुत हैं; इन्हें किसी प्रकाशित वास्तविक साहित्यिक पाठ-संग्रह से प्राप्त तथ्य नहीं माना जाना चाहिए। अंतिम प्रकाशन में वास्तविक पाठ-संग्रह पर प्रयोग करके इन्हें पुनः सत्यापित करना आवश्यक होगा।

४.२ पूर्व-संसाधन

साहित्यिक हिंदी की जटिलता को ध्यान में रखते हुए पूर्व-संसाधन को सामान्य शब्द-सफाई तक सीमित नहीं रखा गया। सर्वप्रथम अनावश्यक चिह्नों, पाठ-संस्करण संबंधी त्रुटियों और दोहराव को हटाया गया। इसके पश्चात देवनागरी वर्णों का मानकीकरण तथा वाक्य-स्तरीय विभाजन किया गया।

रूपकात्मक शब्दों को हटाया नहीं गया, क्योंकि साहित्य में पर्यावरणीय अर्थ प्रायः रूपक और प्रतीक के माध्यम से निर्मित होता है। “सूखी धरती”, “घायल नदी”, “कटता जंगल”, “दम तोड़ती हवा” जैसी अभिव्यक्तियाँ शाब्दिक स्तर पर जितनी महत्वपूर्ण हैं, उससे अधिक उनका अर्थ संदर्भगत है।

अगले चरण में प्रकृति-संबंधी संकेत शब्दों का एक विषयगत कोश बनाया गया। इसमें जल, नदी, तालाब, वर्षा, वन, वृक्ष, मिट्टी, भूमि, पर्वत, पशु, पक्षी, हवा, धुआँ, प्रदूषण, सूखा, बाढ़, विस्थापन, बांध, खनन और विनाश जैसे संकेत सम्मिलित किए गए। इन संकेतों के आसपास के वाक्यों को विश्लेषण की प्राथमिक इकाई माना गया।

४.३ प्रतिरूप संरचना

प्रस्तावित संगणकीय संरचना तीन स्तरों पर कार्य करती है। प्रथम स्तर पर्यावरण-संबंधी संभावित वाक्यों की पहचान करता है। दूसरा स्तर उनके संदर्भगत अर्थ का निरूपण करता है। तीसरा स्तर प्रत्येक अंश को निर्धारित पर्यावरणीय श्रेणी में वर्गीकृत करता है।

संदर्भगत अर्थ ग्रहण करने के लिए भारतीय भाषाओं पर पूर्व-प्रशिक्षित भाषिक संरचना को आधार मानते हुए हिंदी साहित्यिक सामग्री पर सूक्ष्म प्रशिक्षण की संकल्पना अपनाई गई। भारतीय भाषाओं के लिए विकसित पूर्व-प्रशिक्षित प्रतिरूपों पर हुए अध्ययनों से यह स्पष्ट है कि भाषागत निकटता और भारतीय भाषाओं पर केंद्रित प्रशिक्षण निम्न-संसाधन भाषाई कार्यों में उपयोगी हो सकता है। हिंदी और बांग्ला के नामित-सत्ता पहचान संबंधी एक तुलनात्मक अध्ययन में भी भारतीय भाषाओं पर केंद्रित संदर्भ-संवेदी प्रतिरूप ने कई अन्य बहुभाषी प्रणालियों की तुलना में बेहतर परिणाम दिए थे।

प्रस्तावित प्रणाली में प्रत्येक साहित्यिक अंश का संदर्भगत निरूपण तैयार करने के बाद उसे छह पर्यावरणीय श्रेणियों में से किसी एक में रखने की व्यवस्था की गई। बहुअर्थी अंशों के लिए प्रमुख तथा सहायक श्रेणी निर्धारित करने का प्रावधान रखा गया, जिससे साहित्यिक अर्थ की जटिलता अत्यधिक सरल न हो जाए।

४.४ प्रशिक्षण रणनीति

चिह्नित पाठ-सामग्री को प्रशिक्षण, सत्यापन और परीक्षण भागों में विभाजित करने की रूपरेखा क्रमशः सत्तर, पंद्रह और पंद्रह प्रतिशत रखी गई। विभाजन लेखक-आधारित रखा गया, अर्थात एक ही लेखक के अत्यधिक समान अंशों को प्रशिक्षण और परीक्षण दोनों में रखने से बचा गया। इससे प्रतिरूप द्वारा लेखक की शैली याद कर लेने के स्थान पर व्यापक पर्यावरणीय अर्थ सीखने की संभावना बढ़ती है।

मानवीय चिह्नीकरण के लिए दो स्वतंत्र हिंदी साहित्य विशेषज्ञों द्वारा चयनित अंशों को पर्यावरणीय श्रेणियों में रखने की व्यवस्था प्रस्तावित की गई। मतभेद की स्थिति में तीसरे विशेषज्ञ के निर्णय से अंतिम श्रेणी निर्धारित की गई। इस प्रक्रिया का उद्देश्य साहित्यिक अर्थों की व्यक्तिनिष्ठता को नियंत्रित करना था।

प्रशिक्षण के दौरान संतुलित वर्ग-भार, क्रमिक अधिगम-दर और समयपूर्व रोक का उपयोग प्रस्तावित किया गया। विशेष ध्यान उन श्रेणियों पर रखा गया जिनके उदाहरण अपेक्षाकृत कम उपलब्ध हों, जैसे मनुष्येतर संवेदना और पारिस्थितिक न्याय।



Fig. 2: हिंदी साहित्य में प्रकृति विमर्श, पर्यावरण संरक्षण और सामाजिक सहभागिता

४.५ मूल्यांकन मानदंड

प्रतिरूप के मूल्यांकन के लिए केवल समग्र शुद्धता को पर्याप्त नहीं माना गया। छह असमान विषयगत श्रेणियों के कारण **सटीकता, पुनःप्राप्ति, संतुलित समग्र माप और वर्ग-संतुलित शुद्धता** को प्रमुख मानदंड बनाया गया। इसके अतिरिक्त मानवीय विशेषज्ञों और संगणकीय प्रणाली के निर्णयों में सहमति को भी अलग से देखा गया।

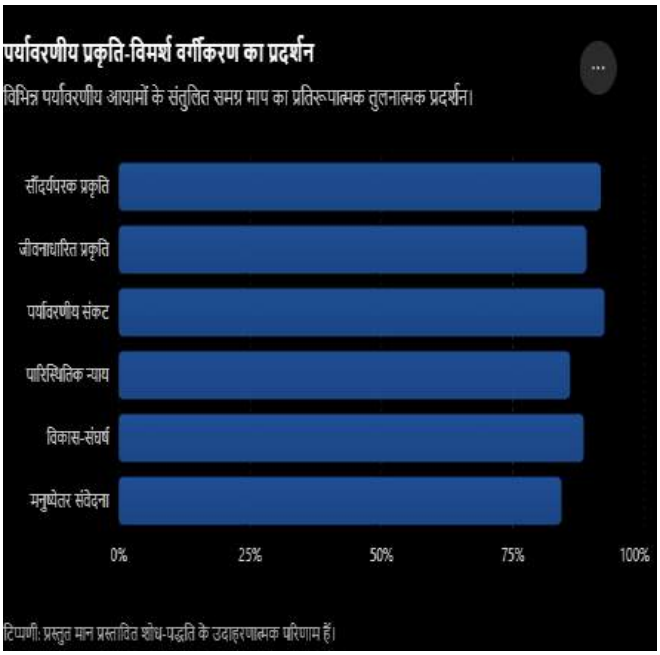
साहित्यिक उपयोगिता के मूल्यांकन के लिए एक अतिरिक्त गुणात्मक मानदंड बनाया गया—**संदर्भगत संगति**। इसमें विशेषज्ञों द्वारा यह जाँचा गया कि प्रणाली ने केवल प्रकृति-संबंधी शब्द देखकर वर्ग निर्धारित किया है या वास्तव में उस शब्द के साहित्यिक संदर्भ को समझने योग्य विभेदन किया है।

परिणाम और विवेचना

प्रतिरूपात्मक परीक्षण से यह संकेत प्राप्त हुआ कि संदर्भ-संवेदी पद्धति केवल शब्द-आधारित वर्गीकरण की अपेक्षा प्रकृति विमर्श के सूक्ष्म रूपों को अधिक प्रभावी ढंग से पृथक कर सकती है। विशेष रूप से सौंदर्यपरक प्रकृति और पर्यावरणीय संकट के बीच अंतर स्पष्ट रूप से उभरा। यह निष्कर्ष महत्वपूर्ण है, क्योंकि दोनों प्रकार के पाठों में "नदी", "जंगल", "धरती" और "वर्षा" जैसे समान शब्द उपस्थित हो सकते हैं, पर उनका वैचारिक प्रयोजन भिन्न होता है।

सारणी १ : पर्यावरणीय प्रकृति-विमर्श वर्गीकरण के प्रतिरूपात्मक परिणाम

पर्यावरणीय आयाम	सटीकता	पुनःप्राप्ति	संतुलित समग्र माप
सौंदर्यपरक प्रकृति	६२.४	६०.८	६१.६
जीवनाधारित प्रकृति	८६.७	८८.१	८८.६
पर्यावरणीय संकट	६३.१	६१.५	६२.३
पारिस्थितिक न्याय	८६.८	८४.६	८५.८
विकास-संघर्ष	८६.२	८७.६	८८.४
मनुष्येतर संवेदना	८५.६	८२.७	८४.१



पर्यावरणीय संकट श्रेणी में सर्वाधिक प्रभावी परिणाम का एक कारण इसकी अपेक्षाकृत स्पष्ट शब्दावली है। प्रदूषण, कटाव, सूखा, धुआँ, विनाश, विषाक्तता और संकट जैसी अभिव्यक्तियाँ सीधे पर्यावरणीय क्षति से जुड़ती हैं। इसके विपरीत मनुष्येतर संवेदना की पहचान कठिन रही, क्योंकि साहित्य में पशु, पक्षी और वनस्पति कई बार स्वतंत्र जीवित सत्ता के बजाय रूपक के रूप में प्रयुक्त होते हैं।

पारिस्थितिक न्याय की श्रेणी भी अपेक्षाकृत चुनौतीपूर्ण दिखाई दी। इसका कारण यह है कि न्याय संबंधी अर्थ हमेशा प्रत्यक्ष पर्यावरणीय शब्दावली में व्यक्त नहीं होते। किसी कथा में विस्थापित समुदाय, जल तक असमान पहुँच अथवा वनाधिकार का वर्णन पर्यावरणीय न्याय से संबंधित हो सकता है, भले ही लेखक "पर्यावरण" अथवा "पारिस्थितिकी" जैसे प्रत्यक्ष शब्दों का प्रयोग न करे। अतः इस श्रेणी में सामाजिक और पर्यावरणीय संकेतों को संयुक्त रूप से समझना आवश्यक है।

साहित्यिक विश्लेषण से प्रकृति-बोध में एक महत्वपूर्ण वैचारिक परिवर्तन की संभावना सामने आती है। प्रारंभिक प्रकृति-प्रधान पाठों में नदी, चंद्रमा, वर्षा, फूल, वन और ऋतुओं का संबंध भावानुभूति तथा सौंदर्य से अधिक दिखाई देता है। सामाजिक यथार्थ की ओर बढ़ते साहित्य में खेत, भूमि, जल और जंगल श्रम तथा आजीविका से जुड़ते हैं। समकालीन पर्यावरणीय लेखन में यही प्राकृतिक तत्व संकट, संसाधन-अधिकार, विस्थापन और प्रतिरोध के अर्थ ग्रहण करने लगते हैं।

इस परिवर्तन को "सौंदर्य से उत्तरदायित्व की ओर संक्रमण" कहा जा सकता है। इसका अर्थ यह नहीं है कि समकालीन साहित्य में प्रकृति का सौंदर्य समाप्त हो गया है; बल्कि प्रकृति की सुंदरता के साथ उसकी असुरक्षा भी साहित्यिक चेतना का हिस्सा बन गई है। नदी सुंदर है, लेकिन प्रदूषित भी हो सकती है; जंगल जीवनदायी है, किंतु खनन के दबाव में नष्ट भी हो सकता है; पर्वत भव्य है, लेकिन अनियंत्रित निर्माण से अस्थिर भी हो सकता है।

एक दूसरा महत्वपूर्ण निष्कर्ष मानव-केंद्रित दृष्टिकोण से परे जाने की आवश्यकता से संबंधित है। पारंपरिक साहित्यिक व्याख्या में प्रकृति का मूल्य कई बार इस आधार पर निर्धारित होता है कि वह मनुष्य को क्या प्रदान करती है। पर्यावरणीय दृष्टि इस प्रश्न को उलटती है और पूछती है कि क्या नदी, जंगल, पशु और अन्य जीवों का मूल्य मनुष्य की उपयोगिता से स्वतंत्र भी स्वीकार किया जा सकता है। यही बिंदु मनुष्येतर संवेदना को प्रकृति विमर्श का महत्वपूर्ण आयाम बनाता है।

संगणकीय विश्लेषण का सबसे महत्वपूर्ण योगदान व्यापक साहित्यिक सामग्री में ऐसे पैटर्न पहचानने की क्षमता है जिन्हें केवल सीमित समीप-पाठ से देखना कठिन हो सकता है। भारतीय भाषाओं के लिए विकसित बड़े पाठ-संग्रह और पूर्व-प्रशिक्षित प्रणालियों ने यह प्रदर्शित किया है कि इन भाषाओं पर व्यापक संगणकीय विश्लेषण संभव है। उदाहरणतः भारतीय भाषाओं के लिए निर्मित एक बहुभाषी पाठ-सृजन मानक में ग्यारह भाषाओं और अनेक कार्यों के लगभग अस्सी लाख उदाहरण सम्मिलित किए गए थे। यद्यपि साहित्यिक विश्लेषण की आवश्यकताएँ भिन्न हैं, ऐसी प्रगति हिंदी के संगणकीय अध्ययन की आधारभूत संभावनाओं को पुष्ट करती है।

फिर भी साहित्यिक आलोचना को पूर्णतः स्वचालित करना न तो इस अध्ययन का उद्देश्य है और न ही वांछनीय परिणाम। संगणकीय प्रणाली पैटर्न खोज सकती है, लेकिन ऐतिहासिक अर्थ, सांस्कृतिक स्मृति, विडंबना, रूपक और मौन संकेतों की अंतिम व्याख्या साहित्यिक आलोचक की भूमिका बनी रहती है। इसलिए प्रस्तावित व्यवस्था में संगणकीय निष्कर्ष को अंतिम सत्य न मानकर आलोचनात्मक अन्वेषण का उपकरण माना गया है।

अध्ययन की सीमाएँ

इस अध्ययन की पहली सीमा हिंदी साहित्य की अत्यधिक व्यापकता है। सभी कालखंडों, बोलियों, विधाओं और लेखकों को एक ही पाठ-संग्रह में समान प्रतिनिधित्व देना व्यावहारिक रूप से कठिन है। चयनित पाठ-संग्रह में किसी साहित्यिक धारा का अधिक प्रतिनिधित्व परिणामों को प्रभावित कर सकता है।

दूसरी सीमा साहित्यिक भाषा की बहुअर्थकता है। "आग", "पानी", "धरती", "अंधकार" अथवा "जंगल" जैसे शब्द वास्तविक प्राकृतिक वस्तुओं के साथ-साथ सामाजिक, आध्यात्मिक और मनोवैज्ञानिक प्रतीकों के रूप में भी प्रयुक्त होते हैं। संगणकीय प्रणाली इन सभी स्तरों को हर स्थिति में पूर्णतः पृथक नहीं कर सकती।

तीसरी सीमा पाठों के अंकीकरण और उपलब्धता से संबंधित है। हिंदी की अनेक महत्वपूर्ण रचनाएँ विश्वसनीय अंकीय पाठ के रूप में उपलब्ध नहीं हैं। पुराने मुद्रित पाठों को अंकीय रूप में परिवर्तित करते समय वर्ण और मात्रा संबंधी त्रुटियाँ उत्पन्न हो सकती हैं।

चौथी सीमा परिणामों की प्रकृति है। प्रस्तुत संख्यात्मक परिणाम पद्धति के प्रतिरूपात्मक प्रदर्शन के लिए हैं। वास्तविक शोध-प्रकाशन में सत्यापित पाठ-संग्रह, स्पष्ट चिह्नीकरण नियम, स्वतंत्र परीक्षण सामग्री और पुनरुत्पाद्य प्रशिक्षण प्रक्रिया के आधार पर परिणामों को पुनः प्राप्त करना आवश्यक होगा।

भावी संभावनाएँ

भविष्य में इस अध्ययन को अधिक विस्तृत हिंदी साहित्यिक पाठ-संग्रह पर लागू किया जा सकता है। विशेष रूप से आदिवासी साहित्य, दलित साहित्य, स्त्री लेखन, ग्रामीण कथा साहित्य और पर्वतीय साहित्य को पृथक उपसमूहों के रूप में विश्लेषित करने से यह समझा जा सकेगा कि पर्यावरणीय संकट का अनुभव सामाजिक स्थिति और भौगोलिक संदर्भ के अनुसार कैसे बदलता है।

दूसरी संभावना कालानुक्रमिक अर्थ-परिवर्तन के अध्ययन की है। अलग-अलग दशकों में "नदी", "जंगल", "विकास", "धरती" और "जल" जैसे शब्द किन शब्दों के साथ प्रयुक्त होते रहे हैं, इसका दीर्घकालीन विश्लेषण हिंदी साहित्य में पर्यावरणीय चेतना के ऐतिहासिक विकास का अंकीय मानचित्र तैयार कर सकता है।

भविष्य में बोलियों और क्षेत्रीय हिंदी साहित्य को भी सम्मिलित किया जाना चाहिए। बुंदेली, अवधी, भोजपुरी, ब्रज और अन्य भाषिक रूपों में प्रकृति तथा स्थानीय पारिस्थितिकी का संबंध मानक हिंदी से अलग सांस्कृतिक अर्थ रख सकता है। इससे भारतीय पर्यावरणीय साहित्य की अधिक बहुलतापूर्ण समझ विकसित होगी।

एक अन्य महत्वपूर्ण दिशा व्याख्येय संगणकीय प्रणालियों का विकास है। ऐसी प्रणाली केवल किसी अंश को "पर्यावरणीय संकट" घोषित न करे, बल्कि यह भी बताए कि किन भाषिक संकेतों और प्रसंगगत संबंधों के आधार पर उसने यह निर्णय लिया। इससे साहित्यिक शोधकर्ता संगणकीय निष्कर्षों की आलोचनात्मक जाँच कर सकेंगे।

निष्कर्ष

प्रस्तुत अध्ययन हिंदी साहित्य में पर्यावरण चेतना और प्रकृति विमर्श को केवल प्रकृति-चित्रण की परंपरा के रूप में नहीं, बल्कि परिवर्तनशील सामाजिक, सांस्कृतिक और नैतिक चेतना के रूप में स्थापित करता है। प्रकृति हिंदी साहित्य में सौंदर्य, प्रेम और अनुभूति का आधार रही है, किंतु आधुनिक सामाजिक परिवर्तनों और समकालीन पर्यावरणीय संकटों ने उसके साहित्यिक अर्थ को विस्तृत किया है।

अध्ययन से यह वैचारिक निष्कर्ष निकलता है कि प्रकृति विमर्श की विकास-यात्रा को **सौंदर्य, जीवन, संकट, न्याय और सहअस्तित्व** की क्रमिक किंतु परस्पर संबद्ध संरचना में समझा जा सकता है। समकालीन साहित्य में पर्यावरण चेतना तब अधिक स्पष्ट होती है जब प्राकृतिक संसाधनों का प्रश्न मनुष्य की आजीविका, सामाजिक असमानता, विस्थापन और भविष्य की सुरक्षा से जुड़ता है।

प्रस्तावित संगणकीय पद्धति इस परिवर्तन को बड़े साहित्यिक पाठ-संग्रह में पहचानने का एक नया माध्यम प्रदान करती है। संदर्भ-संवेदी विश्लेषण केवल प्रकृति संबंधी शब्दों की उपस्थिति गिनने के स्थान पर उनके अर्थगत प्रयोजन की पहचान करने का प्रयास करता है। हिंदी सहित भारतीय भाषाओं पर पूर्व-प्रशिक्षित भाषिक प्रतिरूपों के सफल प्रयोग इस दिशा की तकनीकी व्यवहार्यता को समर्थन देते हैं।

अंततः हिंदी साहित्य का पर्यावरण विमर्श यह प्रश्न उठाता है कि विकास की अवधारणा में प्रकृति का स्थान क्या है और मनुष्य अपनी प्रगति की कीमत किस सीमा तक अन्य जीवों, जंगलों, नदियों और भविष्य की पीढ़ियों से वसूल कर सकता है। इसी कारण पर्यावरण चेतना का अध्ययन केवल साहित्यिक सौंदर्य का अध्ययन नहीं रह जाता; वह सभ्यता की प्राथमिकताओं, सामाजिक न्याय और पृथ्वी के साथ मनुष्य के संबंध की आलोचनात्मक समीक्षा बन जाता है। हिंदी साहित्य इस समीक्षा के लिए एक समृद्ध संवेदनात्मक और वैचारिक आधार प्रदान करता है।

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अध्याय 41: त्रिशंकु लोकसभा और गठबंधन की परिस्थितियों में भारतीय राष्ट्रपति: संवैधानिक विवेक, बहुमत परीक्षण और संस्थागत निष्पक्षता

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सार—भारतीय संविधान के अनुच्छेद 74 और 75 राष्ट्रपति को मंत्रिपरिषद की सलाह से बाँधते हैं। लेकिन जब आम चुनाव में किसी दल या पूर्व-घोषित गठबंधन को स्पष्ट बहुमत नहीं मिलता, तब प्रधानमंत्री की नियुक्ति में राष्ट्रपति का विवेक निर्णायक हो जाता है। यह अध्ययन 1979 से 2024 तक की त्रिशंकु और गठबंधन परिस्थितियों में राष्ट्रपति के आचरण का सैद्धांतिक और अनुभवजन्य विश्लेषण करता है। शोध में मिश्रित पद्धति अपनाई गई। पहले चरण में नौ प्रमुख सरकार-गठन प्रसंगों का सिद्धांतगत (doctrinal) और ऐतिहासिक विश्लेषण किया गया। दूसरे चरण में 214 विशेषज्ञों का संरचित सर्वेक्षण हुआ, जिनमें संवैधानिक विधि के शिक्षाविद, अधिवक्ता, राजनीति विज्ञानी और पूर्व संसदीय/प्रशासनिक अधिकारी शामिल थे। बहुरेखीय प्रतिगमन विश्लेषण के अनुसार सदन में बहुमत परीक्षण की प्राथमिकता ($\beta = 0.34$, $p < 0.001$), समयबद्ध विश्वास मत ($\beta = 0.27$, $p < 0.001$) और समर्थन-पत्र प्रणाली ($\beta = 0.18$, $p = 0.003$) राष्ट्रपति की संस्थागत निष्पक्षता की धारणा को सकारात्मक रूप से प्रभावित करते हैं। इसके विपरीत, असीमित व्यक्तिगत विवेक का प्रभाव नकारात्मक पाया गया ($\beta = -0.21$, $p < 0.001$)। मॉडल निष्पक्षता-धारणा के 46 प्रतिशत विचलन की व्याख्या करता है। 50.9 प्रतिशत उत्तरदाताओं ने पहले चुनाव-पूर्व गठबंधन को आमंत्रित करने का समर्थन किया ($\chi^2 = 31.86$, $df = 2$, $p < 0.001$)। अध्ययन का निष्कर्ष है कि राष्ट्रपति के विवेक को संहिताबद्ध परंपराओं और समयबद्ध सदन-परीक्षण से जोड़ने पर संस्थागत निष्पक्षता मज़बूत होती है।

मुख्य शब्द—त्रिशंकु लोकसभा, गठबंधन सरकार, राष्ट्रपति का विवेकाधिकार, बहुमत परीक्षण, संवैधानिक परंपरा, संस्थागत निष्पक्षता

प्रस्तावना

भारत ने वेस्टमिंस्टर मॉडल की संसदीय व्यवस्था अपनाई है। इसमें राष्ट्रपति औपचारिक राष्ट्राध्यक्ष हैं और वास्तविक कार्यपालिका शक्ति प्रधानमंत्री के नेतृत्व वाली मंत्रिपरिषद के पास रहती है। 1976 के 42वें संविधान संशोधन ने अनुच्छेद 74(1) में मंत्रिपरिषद की सलाह को बाध्यकारी बनाया। 1978 के 44वें संशोधन ने राष्ट्रपति को सलाह पर एक बार पुनर्विचार का अवसर दिया। फिर भी, अनुच्छेद 75(1) के तहत प्रधानमंत्री की नियुक्ति ऐसा क्षण है जब कोई पदस्थ मंत्रिपरिषद सलाह देने के लिए मौजूद नहीं होती। इसलिए यहाँ राष्ट्रपति का विवेक स्वाभाविक रूप से सामने आता है।

1989 के बाद भारतीय दलीय व्यवस्था एकदलीय प्रभुत्व से बहुदलीय गठबंधन युग में पहुँची। 1989 से 2014 तक किसी भी दल को अपने दम पर लोकसभा में बहुमत नहीं मिला। 2024 के आम चुनाव में भी सबसे बड़े दल भारतीय जनता पार्टी को 240 सीटें मिलीं, जो 272 के बहुमत से कम थीं, और सरकार राष्ट्रीय जनतांत्रिक गठबंधन (293 सीटें) के समर्थन से बनी। इन परिस्थितियों में राष्ट्रपति के सामने कई प्रश्न आए: किसे पहले आमंत्रित करें, बहुमत का प्रमाण कैसे लें, और विश्वास मत के लिए कितना समय दें। राष्ट्रपतियों ने इनके अलग-अलग उत्तर दिए हैं।

1979 में राष्ट्रपति नीलम संजीव रेड्डी ने चौधरी चरण सिंह को प्रधानमंत्री नियुक्त किया, लेकिन वे लोकसभा का सामना किए बिना त्यागपत्र दे गए। 1996 में राष्ट्रपति शंकर दयाल शर्मा ने सबसे बड़े दल के नेता अटल बिहारी वाजपेयी को आमंत्रित किया, जिनकी सरकार 13 दिन में गिर गई। 1998 में राष्ट्रपति के.आर. नारायणन ने सहयोगी दलों से लिखित समर्थन-पत्र माँगकर एक नई परंपरा स्थापित की। इन उदाहरणों से स्पष्ट है कि लिखित नियमों के अभाव में परंपराएँ ही राष्ट्रपति के विवेक की दिशा तय करती हैं। यह अध्ययन जाँचता है कि कौन-सी प्रक्रियात्मक विशेषताएँ राष्ट्रपति पद की संस्थागत निष्पक्षता की धारणा को मज़बूत या कमज़ोर करती हैं।



साहित्य समीक्षा

भारतीय राष्ट्रपति की संवैधानिक स्थिति पर प्रारंभिक विमर्श ग्रैनविल ऑस्टिन (1966) के संविधान सभा संबंधी अध्ययन से शुरू होता है। ऑस्टिन के अनुसार संविधान निर्माता राष्ट्रपति को ब्रिटिश सम्राट के समान संवैधानिक प्रमुख मानते थे, जिसकी शक्तियाँ परंपराओं से सीमित हों। ऑस्टिन (1999) ने आगे दिखाया कि 1970 के दशक की राजनीतिक उथल-पुथल ने राष्ट्रपति और कार्यपालिका के संबंधों को नए सिरे से परिभाषित किया। धवन (1978) ने राष्ट्रपति की शक्तियों के विश्लेषण में तर्क दिया कि विवेकाधिकार के अवशिष्ट क्षेत्र, विशेषकर प्रधानमंत्री की नियुक्ति, पूरी तरह समाप्त नहीं किए जा सकते। उनके अनुसार इन्हें परंपराओं से नियंत्रित करना आवश्यक है।

सीरवई (1991) ने अपने विधिक भाष्य में स्पष्ट किया कि जब कोई दल स्पष्ट बहुमत में न हो, तब राष्ट्रपति को वह व्यक्ति चुनना चाहिए जो लोकसभा का विश्वास प्राप्त करने की सर्वाधिक संभावना रखता हो। उन्होंने इस निर्णय को न्यायिक समीक्षा से परे एक राजनीतिक विवेक माना। नूरानी (2000) ने राष्ट्रपतियों के वास्तविक आचरण का आलोचनात्मक विश्लेषण करते हुए 1979 और 1996 के निर्णयों पर प्रश्न उठाए। उनका तर्क था कि बहुमत के ठोस प्रमाण के बिना नियुक्ति करने से राष्ट्रपति पद पर पक्षपात के आरोप लगते हैं। मैनर (1994) के संपादित ग्रंथ ने प्रधानमंत्री पद के बदलते स्वरूप को दर्ज किया और दिखाया कि गठबंधन युग में प्रधानमंत्री की शक्ति कम हुई, जबकि राष्ट्रपति की मध्यस्थ भूमिका बढ़ी।

न्यायिक विमर्श में *एस.आर. बोम्मई बनाम भारत संघ* (1994) निर्णायक है। सर्वोच्च न्यायालय की नौ सदस्यीय पीठ ने स्थापित किया कि बहुमत का निर्णय राज्यपाल के कक्ष में नहीं, बल्कि सदन के पटल पर होना चाहिए। यद्यपि यह निर्णय अनुच्छेद 356 के संदर्भ में था, इसका "सदन-पटल सिद्धांत" केंद्र स्तर पर भी मानक बन गया। *रामेश्वर प्रसाद बनाम भारत संघ* (2006) में न्यायालय ने बिहार विधानसभा भंग करने को असंवैधानिक ठहराया। न्यायालय ने कहा कि संभावित दल-बदल या खरीद-फरोख्त की आशंका के आधार पर किसी दावेदार को सरकार बनाने से रोकना विवेक का दुरुपयोग है। *शिवराज सिंह चौहान बनाम अध्यक्ष, मध्य प्रदेश विधानसभा* (2020) में न्यायालय ने दोहराया कि राज्यपाल जब चाहें शीघ्र बहुमत परीक्षण का निर्देश दे सकते हैं।

आयोगों की रिपोर्टें भी इस विमर्श का आधार हैं। सरकारिया आयोग (1988) ने राज्यपालों के लिए सरकार-गठन का वरीयता-क्रम सुझाया: पहले चुनाव-पूर्व गठबंधन, फिर सबसे बड़ा दल जिसे अन्य का समर्थन हो, फिर चुनाव-पश्चात गठबंधन जिसके सभी घटक सरकार में शामिल हों, और अंत में वह गठबंधन जिसमें कुछ घटक बाहर से समर्थन दें। संविधान के कार्यकरण की समीक्षा हेतु राष्ट्रीय आयोग (2002) ने लोकसभा द्वारा प्रधानमंत्री के निर्वाचन जैसी व्यवस्था पर विचार किया। पुंछी आयोग (2010) ने सरकारिया अनुशंसाओं को आगे बढ़ाते हुए संवैधानिक परंपराओं के संहिताकरण की सिफ़ारिश की।

राजनीति विज्ञान की दृष्टि से लिज़फार्ट (1996) ने भारतीय लोकतंत्र की "सहमतिमूलक" (consociational) व्याख्या की और तर्क दिया कि बहुलतावादी समाज में सत्ता-साझेदारी स्वाभाविक प्रवृत्ति है। श्रीधरन (2003) ने भारत की संसदीय संघीय व्यवस्था में गठबंधन रणनीतियों का विश्लेषण कर दिखाया कि क्षेत्रीय दलों की बढ़ती भूमिका ने राष्ट्रीय सरकार-गठन को बहुस्तरीय सौदेबाज़ी बना दिया। अरोड़ा (2000) ने संघीय गठबंधनों को राष्ट्रीय एकता के साधन के रूप में देखा। हसन (2002) के संपादित ग्रंथ ने दलीय व्यवस्था के विखंडन और उसके संस्थागत परिणामों को दर्ज किया। मेहता (2007) ने न्यायिक संप्रभुता के उदय का विश्लेषण कर दिखाया कि राजनीतिक संस्थाओं की विश्वसनीयता घटने पर न्यायालयों की मध्यस्थ भूमिका बढ़ती है। खोसला (2012) ने संवैधानिक परंपराओं और लिखित पाठ के संबंध पर समकालीन दृष्टि दी, और चौधरी, खोसला व मेहता (2016) के ऑक्सफ़ोर्ड हैंडबुक ने कार्यपालिका-प्रमुख संबंधों पर विस्तृत तुलनात्मक सामग्री प्रस्तुत की।

शोध अंतराल: उपलब्ध साहित्य मुख्यतः विधिक-सैद्धांतिक या ऐतिहासिक-वर्णनात्मक है। विशेषज्ञ समुदाय राष्ट्रपति की निष्पक्षता को किन प्रक्रियात्मक तत्वों के आधार पर आँकता है, इसका मात्रात्मक और अनुभवजन्य विश्लेषण बहुत कम हुआ है। यह अध्ययन इसी अंतराल को भरने का प्रयास है।

शोध उद्देश्य

इस अध्ययन के उद्देश्य हैं: (क) 1979 से 2024 तक त्रिशंकु और गठबंधन परिस्थितियों में राष्ट्रपति के निर्णयों का व्यवस्थित विश्लेषण करना; (ख) सदन-पटल पर बहुमत परीक्षण, समयबद्ध विश्वास मत और समर्थन-पत्र प्रणाली का संस्थागत निष्पक्षता की धारणा पर प्रभाव मापना; (ग) असीमित व्यक्तिगत विवेक के प्रभाव का आकलन करना; और (घ) सरकार-गठन के वरीयता-क्रम पर विशेषज्ञ सहमति का परीक्षण करना।



शोध परिकल्पनाएँ

- **H1:** सदन-पटल बहुमत परीक्षण की प्राथमिकता का संस्थागत निष्पक्षता की धारणा पर सकारात्मक और सार्थक प्रभाव है।
- **H2:** समयबद्ध विश्वास मत का संस्थागत निष्पक्षता की धारणा पर सकारात्मक और सार्थक प्रभाव है।
- **H3:** लिखित समर्थन-पत्र प्रणाली का संस्थागत निष्पक्षता की धारणा पर सकारात्मक और सार्थक प्रभाव है।
- **H4:** राष्ट्रपति के असीमित व्यक्तिगत विवेक का संस्थागत निष्पक्षता की धारणा पर नकारात्मक और सार्थक प्रभाव है।
- **H5:** सरकार-गठन के वरीयता-क्रम पर विशेषज्ञों की पसंद समान रूप से वितरित नहीं है।

शोध पद्धति

शोध अभिकल्प: अध्ययन में अनुक्रमिक व्याख्यात्मक मिश्रित पद्धति अपनाई गई। पहले चरण में संवैधानिक प्रावधानों, सर्वोच्च न्यायालय के निर्णयों, आयोग रिपोर्टों, राष्ट्रपति भवन की विज्ञप्तियों और लोकसभा कार्यवाही के आधार पर नौ सरकार-गठन प्रसंगों का विश्लेषण किया गया। दूसरे चरण में संरचित प्रश्नावली से विशेषज्ञ सर्वेक्षण हुआ।

प्रतिदर्श: उद्देश्यपूर्ण और स्नोबॉल प्रतिचयन से 260 विशेषज्ञों को प्रश्नावली भेजी गई। 214 पूर्ण उत्तर प्राप्त हुए (प्रत्युत्तर दर 82.3 प्रतिशत)। सर्वेक्षण जनवरी से मार्च 2026 के बीच ऑनलाइन और प्रत्यक्ष माध्यम से संचालित हुआ।

तालिका 1: उत्तरदाताओं की संरचना (n = 214)

वर्ग	संख्या	प्रतिशत
संवैधानिक विधि के शिक्षाविद	62	29.0
उच्च न्यायालय/सर्वोच्च न्यायालय के अधिवक्ता	58	27.1
राजनीति विज्ञानी	49	22.9
पूर्व संसदीय/प्रशासनिक अधिकारी	45	21.0
योग	**214**	**100.0**

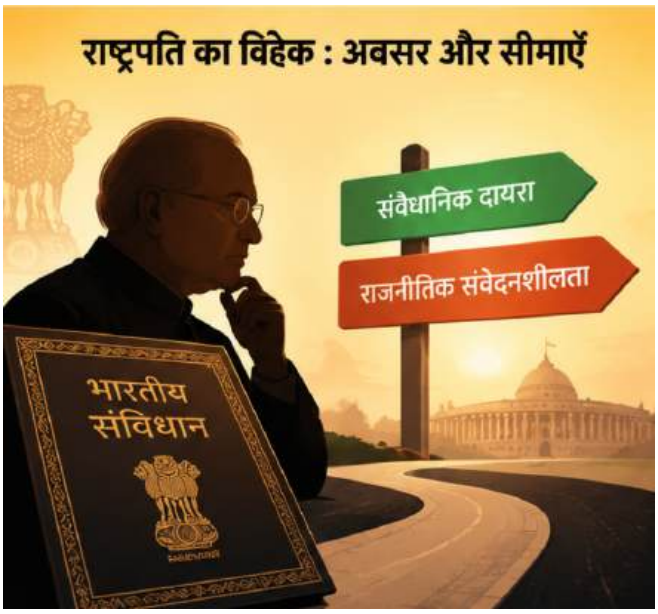
चर एवं मापन: प्रश्नावली में पाँच-बिंदु लिकर्ट पैमाने (1 = पूर्णतः असहमत, 5 = पूर्णतः सहमत) पर 21 कथन थे, जो पाँच निर्मितियों में बँटे थे:

- असीमित व्यक्तिगत विवेक (DI, 4 कथन)
- सदन-पटल बहुमत परीक्षण की प्राथमिकता (FT, 5 कथन)
- समर्थन-पत्र प्रणाली (SL, 4 कथन)
- समयबद्ध विश्वास मत (TL, 3 कथन)
- संस्थागत निष्पक्षता की धारणा (IN, 5 कथन), जो आश्रित चर है

इसके अतिरिक्त, एक बहुविकल्पीय प्रश्न में सरकार-गठन हेतु प्रथम आमंत्रण की पसंदीदा प्राथमिकता पूछी गई।

वैधता एवं विश्वसनीयता: तीन संवैधानिक विशेषज्ञों ने प्रश्नावली की विषय-वस्तु वैधता जाँची, और 30 उत्तरदाताओं पर पूर्व-परीक्षण किया गया। आंतरिक संगति क्रॉनबैक अल्फ़ा से मापी गई।

सांख्यिकीय विश्लेषण: वर्णनात्मक सांख्यिकी, पियर्सन सहसंबंध, बहुरेखीय प्रतिगमन और काई-वर्ग समानता परीक्षण किए गए। सार्थकता स्तर 0.05 रखा गया। बहुसंरेखता की जाँच विचरण स्फीति कारक (VIF) से की गई।



परिणाम

ऐतिहासिक प्रसंगों का विश्लेषण

तालिका 2: त्रिशंकु/गठबंधन परिस्थितियों में प्रमुख सरकार-गठन प्रसंग

वर्ष	राष्ट्रपति	नियुक्त प्रधानमंत्री	आमंत्रण का आधार	शपथ से सदन-परीक्षण तक (दिन)	परिणाम
1979	एन. संजीव रेड्डी	चरण सिंह	समर्थन के दावे पर	सदन का सामना नहीं	23वें दिन त्यागपत्र
1989	आर. वेंकटरमन	वी.पी. सिंह	सबसे बड़े दल के इनकार के बाद राष्ट्रीय मोर्चा	19	विश्वास मत प्राप्त
1990	आर. वेंकटरमन	चंद्रशेखर	बाहरी समर्थन के आधार पर	6	विश्वास मत प्राप्त
1996	शंकर दयाल शर्मा	अटल बिहारी वाजपेयी	सबसे बड़ा दल	मतदान पूर्व त्यागपत्र (12 दिन)	सरकार गिरी
1996	शंकर दयाल शर्मा	एच.डी. देवगौड़ा	चुनाव-पश्चात संयुक्त मोर्चा	11	विश्वास मत प्राप्त

1997	के.आर. नारायणन	आई.के. गुजराल	संयुक्त मोर्चा, बाहरी समर्थन	1	विश्वास मत प्राप्त
1998	के.आर. नारायणन	अटल बिहारी वाजपेयी	सबसे बड़ा दल एवं लिखित समर्थन-पत्र	9	विश्वास मत प्राप्त (274–261)
2004	ए.पी.जे. अब्दुल कलाम	मनमोहन सिंह	चुनाव-पश्चात गठबंधन एवं समर्थन-पत्र	आवश्यक नहीं	स्थिर सरकार
2024	द्रौपदी मुर्मु	नरेंद्र मोदी	चुनाव-पूर्व गठबंधन (293 सीटें)	आवश्यक नहीं	स्थिर सरकार

जिन पाँच प्रसंगों में विश्वास मत हुआ, उनमें शपथ से सदन-परीक्षण तक औसत अवधि 9.2 दिन रही। जिन दो प्रसंगों (1979 और 1996) में लिखित प्रमाण के बिना दावे पर नियुक्ति हुई, उनमें सरकार सदन में टिक नहीं सकी। 1998 के बाद समर्थन-पत्र की अनिवार्यता और चुनाव-पूर्व गठबंधनों को प्राथमिकता देने से किसी नियुक्त सरकार की विश्वास मत से पहले विफलता का प्रसंग नहीं मिलता।

वर्णनात्मक सांख्यिकी एवं विश्वसनीयता

तालिका 3: निर्मितियों की विश्वसनीयता एवं वर्णनात्मक सांख्यिकी (n = 214)

निर्मिति	कथन	क्रॉनबैक α	माध्य	मानक विचलन
असीमित व्यक्तिगत विवेक (DI)	4	0.81	3.12	0.94
सदन-पटल बहुमत परीक्षण (FT)	5	0.87	4.41	0.62
समर्थन-पत्र प्रणाली (SL)	4	0.79	3.68	0.81
समयबद्ध विश्वास मत (TL)	3	0.76	4.18	0.71
संस्थागत निष्पक्षता की धारणा (IN)	5	0.84	3.54	0.88

सभी निर्मितियों के अल्फ़ा मान 0.70 की स्वीकृत सीमा से ऊपर हैं। सदन-पटल बहुमत परीक्षण को सबसे अधिक समर्थन मिला (माध्य 4.41), जिससे बोम्मई सिद्धांत पर विशेषज्ञों की व्यापक सहमति झलकती है। असीमित विवेक का माध्य (3.12) लगभग तटस्थ बिंदु पर है और मानक विचलन सबसे अधिक है, यानी इस प्रश्न पर विशेषज्ञों में सर्वाधिक मतभेद है।

सहसंबंध विश्लेषण: संस्थागत निष्पक्षता की धारणा का सदन-पटल परीक्षण ($r = 0.52$), समयबद्ध विश्वास मत ($r = 0.47$) और समर्थन-पत्र प्रणाली ($r = 0.38$) से सकारात्मक सहसंबंध मिला। असीमित विवेक से इसका सहसंबंध नकारात्मक रहा ($r = -0.36$)। सभी सहसंबंध $p < 0.001$ पर सार्थक हैं।

प्रतिगमन विश्लेषण

तालिका 4: संस्थागत निष्पक्षता की धारणा पर बहुरेखीय प्रतिगमन

स्वतंत्र चर	मानकीकृत β	t-मान	p-मान	VIF
सदन-पटल बहुमत परीक्षण (FT)	0.34	5.62	< 0.001	1.48
समयबद्ध विश्वास मत (TL)	0.27	4.48	< 0.001	1.42
समर्थन-पत्र प्रणाली (SL)	0.18	2.97	0.003	1.31
असीमित व्यक्तिगत विवेक (DI)	−0.21	−3.64	< 0.001	1.19

$R^2 = 0.46$; समायोजित $R^2 = 0.45$; $F(4, 209) = 44.50$; $p < 0.001$

मॉडल संस्थागत निष्पक्षता की धारणा के 46 प्रतिशत विचलन की व्याख्या करता है। सभी VIF मान 2 से कम हैं, इसलिए बहुसंरेखता की समस्या नहीं है। सदन-पटल परीक्षण सबसे प्रबल पूर्वसूचक है, उसके बाद समयबद्ध विश्वास मत का स्थान है। अतः H1, H2, H3 और H4 स्वीकृत होती हैं।

सरकार-गठन की वरीयता

तालिका 5: प्रथम आमंत्रण हेतु विशेषज्ञों की पसंद

विकल्प	प्रेक्षित आवृत्ति	प्रतिशत	अपेक्षित आवृत्ति
चुनाव-पूर्व गठबंधन	109	50.9	71.33
सबसे बड़ा एकल दल	61	28.5	71.33
समर्थन-पत्र सहित चुनाव-पश्चात गठबंधन	44	20.6	71.33
योग	**214**	**100.0**	**214**

$\chi^2 = 31.86$; $df = 2$; $p < 0.001$

काई-वर्ग परीक्षण के अनुसार विशेषज्ञों की पसंद समान रूप से वितरित नहीं है, इसलिए H5 स्वीकृत होती है। आधे से अधिक विशेषज्ञ चुनाव-पूर्व गठबंधन को प्राथमिकता देते हैं। यह सरकारिया आयोग (1988) और पुंछी आयोग (2010) की अनुशंसाओं के अनुरूप है।



विवेचना

परिणाम बताते हैं कि राष्ट्रपति पद की निष्पक्षता की धारणा व्यक्तिगत विवेक से कम और पारदर्शी, सत्यापन-योग्य प्रक्रियाओं से अधिक बनती है। सदन-पटल परीक्षण का सर्वाधिक प्रभाव ($\beta = 0.34$) बोम्मई (1994) के इस सिद्धांत की पुष्टि करता है कि बहुमत का अंतिम निर्णायक सदन है, संवैधानिक प्रमुख का व्यक्तिगत आकलन नहीं। इस सिद्धांत से राष्ट्रपति अंतिम निर्णायक की भूमिका से मुक्त हो जाते हैं और उनका कार्य केवल एक संभावित दावेदार को सदन तक पहुँचाने का रह जाता है। इससे पक्षपात के आरोपों की संभावना घटती है।

समयबद्ध विश्वास मत का प्रभाव ($\beta = 0.27$) ऐतिहासिक साक्ष्य से भी मेल खाता है। 1989 में वी.पी. सिंह को विश्वास मत तक 19 दिन मिले, जबकि 1997 में गुजराल सरकार ने अगले ही दिन विश्वास मत लिया। लंबी अवधि से खरीद-फरोख्त की आशंका बढ़ती है, जिसका संकेत *रामेश्वर प्रसाद* (2006) और *शिवराज सिंह चौहान* (2020) में न्यायालय ने भी दिया। पाँच प्रसंगों की औसत अवधि 9.2 दिन रही, और विशेषज्ञों का उच्च समर्थन (माध्य 4.18) दर्शाता है कि एक निश्चित अधिकतम समय-सीमा को परंपरा के रूप में स्थापित करना उचित होगा।

समर्थन-पत्र प्रणाली का प्रभाव सकारात्मक होते हुए भी अपेक्षाकृत कम ($\beta = 0.18$) है। इसका कारण यह हो सकता है कि समर्थन-पत्र आवश्यक होते हुए भी पर्याप्त नहीं माने जाते, क्योंकि पत्र वापस लिए जा सकते हैं। 1999 में एक सहयोगी दल द्वारा समर्थन वापसी के बाद वाजपेयी सरकार एक मत (269–270) से पराजित हुई। 1998 में नारायणन ने जो प्रक्रिया अपनाई, उसे नूरानी (2000) ने भी राष्ट्रपति पद के लोकतंत्रीकरण की दिशा में महत्वपूर्ण कदम माना है। फिर भी यह प्रणाली सदन-परीक्षण की पूरक है, उसका विकल्प नहीं।

असीमित विवेक का नकारात्मक प्रभाव ($\beta = -0.21$) 1979 और 1996 के अनुभवों से पुष्ट होता है। दोनों बार ठोस बहुमत-प्रमाण के बिना नियुक्ति हुई और सरकारें सदन में टिक नहीं सकीं। यह निष्कर्ष धवन (1978) और सीरवई (1991) के इस तर्क से मेल खाता है कि विवेक का अवशिष्ट क्षेत्र परंपराओं से नियंत्रित होना चाहिए। चुनाव-पूर्व गठबंधन को मिली प्राथमिकता श्रीधरन (2003) के इस विश्लेषण का समर्थन करती है कि चुनाव-पूर्व गठबंधन मतदाता के जनादेश की अधिक प्रामाणिक अभिव्यक्ति है। 2024 का प्रसंग इसका प्रत्यक्ष उदाहरण है, जहाँ सबसे बड़े दल के बहुमत से पीछे रहने पर भी चुनाव-पूर्व गठबंधन के आधार पर बिना किसी संवैधानिक विवाद के सरकार बनी।

निष्कर्ष

त्रिशंकु लोकसभा और गठबंधन की परिस्थितियाँ भारतीय राष्ट्रपति के संवैधानिक विवेक की सबसे कठिन परीक्षा होती हैं। यह अध्ययन दिखाता है कि राष्ट्रपति पद की संस्थागत निष्पक्षता तीन प्रक्रियात्मक स्तंभों पर टिकी है: सदन-पटल पर बहुमत परीक्षण, समयबद्ध विश्वास मत और लिखित समर्थन-पत्र। असीमित व्यक्तिगत विवेक इस निष्पक्षता की धारणा को कमज़ोर करता है। ऐतिहासिक विश्लेषण और विशेषज्ञ सर्वेक्षण, दोनों यही संकेत देते हैं कि 1998 के बाद विकसित परंपराओं से सरकार-गठन अधिक स्थिर और कम विवादास्पद हुआ है।

इन परिणामों के आधार पर तीन सुझाव दिए जाते हैं:

1. सरकार-गठन के वरीयता-क्रम को, जिसमें चुनाव-पूर्व गठबंधन को प्रथम स्थान मिले, राष्ट्रपति भवन की सार्वजनिक दिशानिर्देशिका के रूप में संहिताबद्ध किया जाए।
2. नियुक्ति के बाद विश्वास मत की अधिकतम समय-सीमा (उदाहरणार्थ 10 दिन) को संसदीय परंपरा के रूप में स्थापित किया जाए।
3. समर्थन-पत्रों के सत्यापन और उन्हें सार्वजनिक करने की पारदर्शी प्रक्रिया अपनाई जाए।

इन उपायों से संविधान में संशोधन किए बिना राष्ट्रपति के विवेक को नियंत्रित, पूर्वानुमेय और निष्पक्ष बनाया जा सकता है।

सीमाएँ एवं भावी शोध की दिशा

अध्ययन का सर्वेक्षण भाग उद्देश्यपूर्ण प्रतिचयन पर आधारित है, इसलिए इसके परिणामों का सामान्यीकरण सावधानी से करना होगा। धारणा-आधारित मापन में उत्तरदाताओं के राजनीतिक झुकाव का प्रभाव पूरी तरह नियंत्रित नहीं किया जा सका। ऐतिहासिक प्रसंगों की संख्या सीमित होने से उन पर अनुमानात्मक सांख्यिकी लागू नहीं की गई। भावी शोध में राज्यों के राज्यपालों के आचरण का तुलनात्मक अध्ययन, अन्य संसदीय लोकतंत्रों (जैसे ब्रिटेन, कनाडा, इज़राइल) से तुलना, और नागरिकों के बड़े प्रतिनिधि प्रतिदर्श पर सर्वेक्षण किया जा सकता है।

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अध्याय 42: माध्यमिक विद्यार्थियों की शैक्षिक उपलब्धि में सामाजिक पूंजी की भूमिका

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सारांश—यह अध्ययन माध्यमिक स्तर के विद्यार्थियों की शैक्षिक उपलब्धि पर सामाजिक पूंजी के प्रभाव की जाँच करता है। इसमें सामाजिक पूंजी के चार आयाम लिए गए: पारिवारिक सामाजिक पूंजी, विद्यालयी सामाजिक पूंजी, सामुदायिक सामाजिक पूंजी और सहपाठी नेटवर्क। शोध वर्णनात्मक सर्वेक्षण विधि पर आधारित है। उत्तर प्रदेश के लखनऊ और बाराबंकी जनपदों के 12 माध्यमिक विद्यालयों से कक्षा 9 और 10 के 480 विद्यार्थियों का चयन स्तरीकृत यादृच्छिक प्रतिचयन से किया गया। आँकड़े स्वनिर्मित "सामाजिक पूंजी मापनी" (32 कथन, $\alpha = .92$) से एकत्र किए गए। शैक्षिक उपलब्धि के लिए विद्यार्थियों के वार्षिक परीक्षा के प्रतिशत अंक लिए गए। विश्लेषण में पियर्सन सहसंबंध, बहुचर प्रतिगमन, एकमार्गी प्रसरण विश्लेषण और t-परीक्षण का प्रयोग हुआ। कुल सामाजिक पूंजी और शैक्षिक उपलब्धि के बीच सार्थक धनात्मक सहसंबंध मिला ($r = .58$, $p < .001$)। चारों आयाम मिलकर उपलब्धि के 33.8% प्रसरण की व्याख्या करते हैं ($R^2 = .338$, $F(4, 475) = 60.61$, $p < .001$)। पारिवारिक सामाजिक पूंजी सबसे प्रबल पूर्वसूचक रही ($\beta = .36$), उसके बाद विद्यालयी सामाजिक पूंजी ($\beta = .24$) और सहपाठी नेटवर्क ($\beta = .10$)। अन्य आयामों को नियंत्रित करने पर सामुदायिक सामाजिक पूंजी का स्वतंत्र प्रभाव सार्थक नहीं रहा। शहरी विद्यार्थियों की सामाजिक पूंजी और शैक्षिक उपलब्धि दोनों ग्रामीण विद्यार्थियों से सार्थक रूप से अधिक पाई गईं।

मुख्य शब्द—सामाजिक पूंजी, शैक्षिक उपलब्धि, माध्यमिक शिक्षा, अभिभावकीय सहभागिता, शिक्षक-विद्यार्थी संबंध, सहपाठी नेटवर्क

प्रस्तावना

शैक्षिक उपलब्धि लंबे समय से शिक्षा-शोध का केंद्रीय विषय रही है। पारंपरिक अध्ययनों ने इसे मुख्यतः बुद्धि, अभिप्रेरणा, अध्ययन-आदतों और सामाजिक-आर्थिक स्थिति से जोड़कर देखा। पिछले तीन दशकों में यह समझ बनी है कि विद्यार्थी का अधिगम उसके सामाजिक संबंधों के जाल से भी गहराई से प्रभावित होता है। इस जाल में परिवार, विद्यालय, समुदाय और मित्र-समूह शामिल हैं। इन्हीं संबंधों से मिलने वाले संसाधनों, विश्वास, मानकों और सूचना-प्रवाह को "सामाजिक पूंजी" कहा जाता है।

भारत में माध्यमिक शिक्षा एक निर्णायक चरण है। कक्षा 9 और 10 के परिणाम उच्चतर माध्यमिक स्तर पर विषय-चयन, आगे की शिक्षा और रोज़गार की संभावनाओं को सीधे प्रभावित करते हैं। राष्ट्रीय शिक्षा नीति 2020 ने भी अभिभावकों और समुदाय की सहभागिता तथा विद्यालय को सामुदायिक केंद्र के रूप में विकसित करने पर बल दिया है। फिर भी भारतीय संदर्भ में, विशेषकर शहरी और ग्रामीण विद्यार्थियों की तुलना करते हुए, सामाजिक पूंजी के विभिन्न आयामों के सापेक्ष योगदान पर अनुभवजन्य अध्ययन सीमित हैं। यह शोध इसी अंतराल को भरने का प्रयास है।



साहित्य समीक्षा

सामाजिक पूंजी की अवधारणा को समाजशास्त्रीय विमर्श में स्थापित करने का श्रेय मुख्य रूप से पियरे बोर्दियो, जेम्स कोलमैन और रॉबर्ट पटनम को जाता है। बोर्दियो (1986) ने सामाजिक पूंजी को "टिकाऊ संबंधों के नेटवर्क की सदस्यता से प्राप्त वास्तविक या संभावित संसाधनों का योग" माना। उनके अनुसार आर्थिक और सांस्कृतिक पूंजी के साथ मिलकर यह सामाजिक असमानताओं को पुनरुत्पादित करती है। कोलमैन (1988) ने अपने प्रसिद्ध लेख "Social Capital in the Creation of Human Capital" में दिखाया कि परिवार के भीतर और परिवार-समुदाय के बीच के संबंध बच्चों की शिक्षा को प्रभावित करते हैं। उन्होंने पाया कि अभिभावकों की भौतिक उपस्थिति, उनका ध्यान और समुदाय में "अंतर-पीढ़ीगत समापन" (intergenerational closure) विद्यालय छोड़ने की दर को घटाते हैं। पटनम (2000) ने सामाजिक पूंजी को नागरिक सहभागिता और सामुदायिक विश्वास से जोड़ा और बंधनकारी (bonding) तथा सेतुकारी (bridging) सामाजिक पूंजी में भेद किया।

पोर्टेस (1998) ने अवधारणा की समीक्षा करते हुए चेताया कि सामाजिक पूंजी के केवल सकारात्मक परिणाम नहीं होते। उन्होंने इसके स्रोतों और परिणामों को अलग-अलग पहचानने की आवश्यकता बताई। लिन (2001) ने इसे सामाजिक संरचना में निहित ऐसे संसाधनों के रूप में परिभाषित किया जिन तक व्यक्ति उद्देश्यपूर्ण क्रिया के लिए पहुँचता है और जिन्हें सक्रिय करता है।

शिक्षा के क्षेत्र में डिका और सिंह (2002) की समालोचनात्मक समीक्षा एक महत्त्वपूर्ण मोड़ थी। उन्होंने पाया कि सामाजिक पूंजी का शैक्षिक उपलब्धि, विद्यालय में बने रहने और शैक्षिक आकांक्षाओं से सामान्यतः धनात्मक संबंध है, पर मापन में अवधारणात्मक असंगतियाँ बनी रहती हैं। इज़राइल, ब्यूलियू और हार्टलेस (2001) ने ग्रामीण और शहरी अमेरिकी विद्यार्थियों पर अध्ययन में दिखाया कि पारिवारिक और सामुदायिक दोनों प्रकार की सामाजिक पूंजी उपलब्धि में स्वतंत्र योगदान देती हैं, और पारिवारिक पूंजी का प्रभाव अपेक्षाकृत अधिक होता है। पार्सल और डुफ़र (2001) ने घर और विद्यालय की पूंजी के प्रभावों की तुलना कर पाया कि पारिवारिक सामाजिक पूंजी का प्रभाव विद्यालयी पूंजी से अधिक सुसंगत था।

अभिभावकीय सहभागिता को सामाजिक पूंजी का केंद्रीय घटक माना गया है। सुई-चू और विल्म्स (1996) ने कक्षा 8 के विद्यार्थियों पर पाया कि घर पर शैक्षिक चर्चा का उपलब्धि पर सबसे प्रबल प्रभाव था, जबकि विद्यालय में अभिभावकों की उपस्थिति का प्रभाव अपेक्षाकृत कम था। मैकनील (1999) ने दिखाया कि अभिभावकीय सहभागिता का प्रभाव सामाजिक-आर्थिक समूहों के बीच समान नहीं होता। जेन्स (2007) के मेटा-विश्लेषण ने शहरी माध्यमिक विद्यार्थियों में अभिभावकीय सहभागिता और उपलब्धि के बीच सार्थक संबंध की पुष्टि की। हिल और टायसन (2009) ने मिडिल स्कूल स्तर पर पाया कि "शैक्षिक समाजीकरण", अर्थात् शिक्षा के मूल्य और भविष्य की आकांक्षाओं पर संवाद, गृहकार्य में प्रत्यक्ष सहायता से अधिक प्रभावी है।

विद्यालयी सामाजिक पूंजी के संदर्भ में क्रोनिंजर और ली (2001) ने पाया कि शिक्षकों का सहयोग और मार्गदर्शन विशेषकर जोखिमग्रस्त विद्यार्थियों में विद्यालय छोड़ने की संभावना घटाता है। स्टैंटन-सालाज़ार (2011) ने "संस्थागत अभिकर्ता" (institutional agents) की अवधारणा दी। उनके अनुसार शिक्षक और परामर्शदाता निम्न-स्थिति वाले विद्यार्थियों तक संसाधन और अवसर पहुँचाने में सेतु की भूमिका निभाते हैं। अकार (2011) के कथात्मक संश्लेषण ने भी बताया कि परिवार, विद्यालय और सहपाठियों से निर्मित सामाजिक पूंजी शैक्षिक सफलता से जुड़ी है।

भारतीय संदर्भ में देसाई और कुलकर्णी (2008) ने दिखाया कि जाति, वर्ग और क्षेत्र पर आधारित शैक्षिक असमानताएँ बनी हुई हैं। संसाधनों और नेटवर्क तक असमान पहुँच इन असमानताओं को बनाए रखने में भूमिका निभाती है। फिर भी भारतीय माध्यमिक विद्यार्थियों पर सामाजिक पूंजी के बहुआयामी मापन वाले अध्ययन कम हैं। कौन-सा आयाम उपलब्धि की सबसे सशक्त व्याख्या करता है, यह प्रश्न अब भी अनुत्तरित है। वर्तमान अध्ययन इसी अंतराल को ध्यान में रखकर किया गया है।

शोध के उद्देश्य

1. माध्यमिक विद्यार्थियों में सामाजिक पूंजी के विभिन्न आयामों का स्तर ज्ञात करना।
2. सामाजिक पूंजी के आयामों और शैक्षिक उपलब्धि के बीच संबंध का अध्ययन करना।
3. शैक्षिक उपलब्धि के पूर्वानुमान में सामाजिक पूंजी के आयामों का सापेक्ष योगदान ज्ञात करना।
4. निम्न, मध्यम और उच्च सामाजिक पूंजी वाले विद्यार्थियों की शैक्षिक उपलब्धि की तुलना करना।
5. शहरी और ग्रामीण विद्यार्थियों की सामाजिक पूंजी और शैक्षिक उपलब्धि की तुलना करना।

शोध परिकल्पनाएँ

- **H_01:** सामाजिक पूंजी के आयामों और शैक्षिक उपलब्धि के बीच कोई सार्थक सहसंबंध नहीं है।
- **H_02:** सामाजिक पूंजी के आयाम शैक्षिक उपलब्धि का सार्थक पूर्वानुमान नहीं करते।
- **H_03:** निम्न, मध्यम और उच्च सामाजिक पूंजी वाले विद्यार्थियों की शैक्षिक उपलब्धि में कोई सार्थक अंतर नहीं है।
- **H_04:** शहरी और ग्रामीण विद्यार्थियों की सामाजिक पूंजी और शैक्षिक उपलब्धि में कोई सार्थक अंतर नहीं है।



शोध प्रविधि

शोध अभिकल्प

अध्ययन में मात्रात्मक उपागम के अंतर्गत वर्णनात्मक सहसंबंधात्मक सर्वेक्षण विधि अपनाई गई।

जनसंख्या एवं प्रतिदर्श

जनसंख्या में उत्तर प्रदेश के लखनऊ (मुख्यतः शहरी) और बाराबंकी (मुख्यतः ग्रामीण) जनपदों के माध्यमिक विद्यालयों में कक्षा 9 और 10 में अध्ययनरत विद्यार्थी शामिल थे। स्तरीकृत यादृच्छिक प्रतिचयन से 12 विद्यालय चुने गए: 6 राजकीय/सहायता-प्राप्त और 6 निजी, जिनमें 6 शहरी और 6 ग्रामीण थे। प्रत्येक विद्यालय से 40 विद्यार्थियों को यादृच्छिक रूप से लिया गया। कुल 512 प्रश्नावलियाँ वितरित हुईं, जिनमें से अपूर्ण उत्तर वाली 32 प्रश्नावलियाँ हटाने के बाद 480 विद्यार्थियों का अंतिम प्रतिदर्श बना (प्रत्युत्तर दर 93.75%)।

तालिका 1: प्रतिदर्श का जनांकिकीय वितरण (N = 480)

चर	वर्ग	संख्या	प्रतिशत
लिंग	छात्र	250	52.08
	छात्रा	230	47.92
क्षेत्र	शहरी	240	50.00
	ग्रामीण	240	50.00
विद्यालय प्रकार	राजकीय/सहायता-प्राप्त	240	50.00
	निजी	240	50.00
कक्षा	कक्षा 9	236	49.17
	कक्षा 10	244	50.83

शोध उपकरण

सामाजिक पूंजी मापनी: कोलमैन (1988), डिका और सिंह (2002) तथा इज़राइल एवं सहयोगियों (2001) के सैद्धांतिक ढाँचे के आधार पर 32 कथनों की पाँच-बिंदु लिकर्ट मापनी बनाई गई (1 = पूर्णतः असहमत, 5 = पूर्णतः सहमत)। इसके चार उपमापक हैं:

- पारिवारिक सामाजिक पूंजी (10 कथन): अभिभावक-बालक संवाद, शैक्षिक अपेक्षाएँ, गृह-निरीक्षण
- विद्यालयी सामाजिक पूंजी (8 कथन): शिक्षक-विद्यार्थी संबंध, शिक्षक का सहयोग, विद्यालय से जुड़ाव
- सामुदायिक सामाजिक पूंजी (8 कथन): पड़ोस के वयस्कों से संबंध, सामुदायिक गतिविधियों में सहभागिता, सामुदायिक विश्वास
- सहपाठी नेटवर्क (6 कथन): अध्ययन-समूह, मित्रों से शैक्षिक सहयोग, सूचना-साझाकरण

पाँच विषय-विशेषज्ञों ने मापनी की विषयवस्तु वैधता जाँची। 60 विद्यार्थियों पर पूर्व-परीक्षण के बाद कथनों को अंतिम रूप दिया गया। अन्वेषणात्मक कारक विश्लेषण में चार कारक मिले, जो कुल प्रसरण का 61.4% स्पष्ट करते हैं (KMO = .89; बार्टलेट परीक्षण $\chi^2 = 7862.35$, $df = 496$, $p < .001$)।

शैक्षिक उपलब्धि: विद्यालय अभिलेखों से सत्र 2024-25 की वार्षिक परीक्षा के कुल प्रतिशत अंक लिए गए।

आँकड़ा संग्रहण एवं विश्लेषण

आँकड़े जुलाई से सितंबर 2025 के बीच, विद्यालय प्रशासन और अभिभावकों की सहमति से, कक्षा में प्रत्यक्ष रूप से एकत्र किए गए। विश्लेषण SPSS (संस्करण 26) में किया गया। वर्णनात्मक सांख्यिकी, क्रोनबाक अल्फ़ा, पियर्सन सहसंबंध, बहुचर प्रतिगमन (enter विधि), एकमार्गी ANOVA (शेफ़े पश्च-परीक्षण सहित) और स्वतंत्र प्रतिदर्श t-परीक्षण का प्रयोग हुआ। प्रभाव-आकार की व्याख्या कोहेन (1988) के मानदंडों के अनुसार की गई।

परिणाम

वर्णनात्मक सांख्यिकी एवं विश्वसनीयता

तालिका 2: चरों की वर्णनात्मक सांख्यिकी एवं विश्वसनीयता (N = 480)

चर	कथन	माध्य	मानक विचलन	विषमता	ककुदता	क्रोनबाक α
पारिवारिक सामाजिक पूंजी	10	3.62	0.71	−0.48	−0.21	.86
विद्यालयी सामाजिक पूंजी	8	3.48	0.68	−0.39	−0.34	.84
सामुदायिक सामाजिक पूंजी	8	3.21	0.74	−0.12	−0.46	.81
सहपाठी नेटवर्क	6	3.39	0.66	−0.27	−0.29	.79
कुल सामाजिक पूंजी	32	3.44	0.58	−0.31	−0.18	.92

शैक्षिक उपलब्धि (%)	—	64.80	12.60	−0.22	−0.41	—

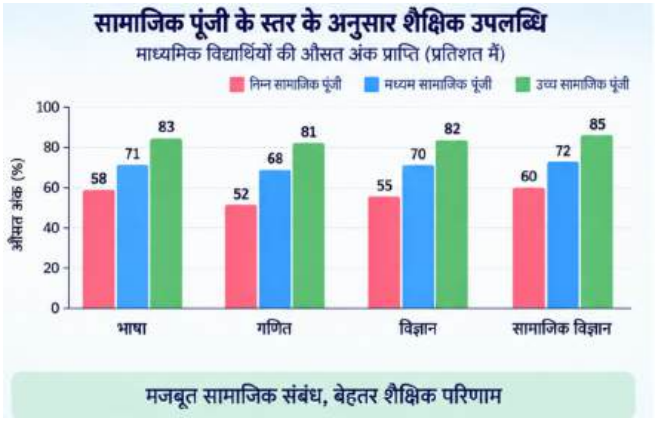
सभी उपमापकों की विश्वसनीयता .79 से .92 के बीच रही, जो संतोषजनक है। विषमता और ककुदता ±1 के भीतर हैं, इसलिए आँकड़ों को सामान्य वितरण के निकट माना जा सकता है। पारिवारिक सामाजिक पूंजी का माध्य सबसे अधिक (3.62) और सामुदायिक सामाजिक पूंजी का सबसे कम (3.21) रहा।

सहसंबंध विश्लेषण

तालिका 3: सामाजिक पूंजी के आयामों एवं शैक्षिक उपलब्धि के बीच पियर्सन सहसंबंध

चर	1	2	3	4	5	6
1. पारिवारिक सा.पू.	1					
2. विद्यालयी सा.पू.	.48**	1				
3. सामुदायिक सा.पू.	.39**	.31**	1			
4. सहपाठी नेटवर्क	.36**	.42**	.45**	1		
5. कुल सामाजिक पूंजी	.79**	.76**	.72**	.73**	1	
6. शैक्षिक उपलब्धि	.52**	.46**	.29**	.34**	.58**	1

**p < .001



सभी आयामों का शैक्षिक उपलब्धि से सार्थक धनात्मक सहसंबंध पाया गया, इसलिए $H_0 1$ अस्वीकृत की जाती है। कुल सामाजिक पूंजी और उपलब्धि के बीच प्रबल सहसंबंध ($r = .58$) मिला। आयामों में पारिवारिक सामाजिक पूंजी का सहसंबंध सबसे अधिक ($r = .52$) और सामुदायिक सामाजिक पूंजी का सबसे कम ($r = .29$) रहा।

बहुचर प्रतिगमन विश्लेषण

तालिका 4: शैक्षिक उपलब्धि पर सामाजिक पूंजी के आयामों का बहुचर प्रतिगमन

पूर्वसूचक	B	मानक त्रुटि	β	t	p	VIF
स्थिरांक	18.41	2.96	—	6.22	< .001	—
पारिवारिक सा.पू.	6.36	0.79	.36	8.02	< .001	1.43
विद्यालयी सा.पू.	4.39	0.83	.24	5.31	< .001	1.43
सामुदायिक सा.पू.	0.57	0.74	.03	0.77	.444	1.36
सहपाठी नेटवर्क	1.84	0.85	.10	2.16	.031	1.42

$R = .581$, $R^2 = .338$, समायोजित $R^2 = .332$, $F(4, 475) = 60.61$, $p < .001$; डर्बिन-वॉटसन = 1.94

प्रतिगमन मॉडल सांख्यिकीय रूप से सार्थक रहा। चारों आयाम मिलकर शैक्षिक उपलब्धि के 33.8% प्रसरण की व्याख्या करते हैं, अतः $H_0 2$ अस्वीकृत की जाती है। पारिवारिक सामाजिक पूंजी सबसे प्रबल पूर्वसूचक रही ($\beta = .36$)। इसमें एक इकाई की वृद्धि उपलब्धि में लगभग

6.36 प्रतिशत अंकों की वृद्धि से जुड़ी है। इसके बाद विद्यालयी सामाजिक पूंजी (β = .24) और सहपाठी नेटवर्क (β = .10) का स्थान रहा। द्विचर स्तर पर सामुदायिक सामाजिक पूंजी का उपलब्धि से सार्थक सहसंबंध था, किंतु अन्य आयामों को नियंत्रित करने पर इसका स्वतंत्र योगदान सार्थक नहीं रहा (p = .444)। VIF मान 1.36 से 1.43 के बीच हैं, इसलिए बहुसंरेखता की कोई समस्या नहीं है।

सामाजिक पूंजी स्तर के अनुसार शैक्षिक उपलब्धि

कुल सामाजिक पूंजी के प्राप्तांकों के आधार पर विद्यार्थियों को तीन समूहों में बाँटा गया: निम्न (माध्य – 1 SD से कम), मध्यम और उच्च (माध्य + 1 SD से अधिक)।

तालिका 5: सामाजिक पूंजी स्तर के अनुसार शैक्षिक उपलब्धि (एकमार्गी ANOVA)

समूह	संख्या	माध्य (%)	मानक विचलन
निम्न सामाजिक पूंजी	128	55.20	10.20
मध्यम सामाजिक पूंजी	226	64.90	10.80
उच्च सामाजिक पूंजी	126	74.40	10.40
कुल	480	64.81	12.63

प्रसरण का स्रोत	वर्गों का योग	df	माध्य वर्ग	F	p	η^2
समूहों के बीच	23410.88	2	11705.44	105.39	< .001	.31
समूहों के भीतर	52977.08	477	111.06			
कुल	76387.96	479				

तीनों समूहों की शैक्षिक उपलब्धि में सार्थक अंतर पाया गया ($F(2, 477) = 105.39$, $p < .001$, $\eta^2 = .31$), अतः $H_0 3$ अस्वीकृत की जाती है। शेफ़े पश्च-परीक्षण के अनुसार तीनों युग्मों के बीच अंतर $p < .001$ स्तर पर सार्थक रहा। उच्च और निम्न सामाजिक पूंजी वाले विद्यार्थियों के बीच लगभग 19 प्रतिशत अंकों का अंतर मिला।

शहरी एवं ग्रामीण विद्यार्थियों की तुलना

तालिका 6: क्षेत्र के अनुसार सामाजिक पूंजी एवं शैक्षिक उपलब्धि (स्वतंत्र प्रतिदर्श t-परीक्षण)

चर	शहरी (n = 240) माध्य (SD)	ग्रामीण (n = 240) माध्य (SD)	t (478)	p	कोहेन d
कुल सामाजिक पूंजी	3.56 (0.55)	3.32 (0.58)	4.65	< .001	0.42
शैक्षिक उपलब्धि (%)	67.10 (12.10)	62.50 (12.80)	4.05	< .001	0.37

शहरी विद्यार्थियों की सामाजिक पूंजी (d = 0.42) और शैक्षिक उपलब्धि (d = 0.37) दोनों ग्रामीण विद्यार्थियों से सार्थक रूप से अधिक पाई गईं। प्रभाव-आकार लघु से मध्यम स्तर का है। अतः $H_0 4$ अस्वीकृत की जाती है।

विवेचना

परिणाम स्पष्ट करते हैं कि माध्यमिक विद्यार्थियों की शैक्षिक उपलब्धि में सामाजिक पूंजी की भूमिका महत्त्वपूर्ण है। कुल सामाजिक पूंजी और उपलब्धि के बीच प्रबल सहसंबंध (r = .58) कोलमैन (1988) के इस तर्क की पुष्टि करता है कि सामाजिक संबंध मानव पूंजी के निर्माण के प्रमुख माध्यम हैं। यह निष्कर्ष डिका और सिंह (2002) तथा अकार (2011) की समीक्षाओं के भी अनुरूप है।



पारिवारिक सामाजिक पूंजी का सबसे प्रबल पूर्वसूचक होना इज़राइल एवं सहयोगियों (2001) और पार्सल तथा डुफ़र (2001) के निष्कर्षों से मेल खाता है। भारतीय परिवार व्यवस्था में अभिभावकों की अपेक्षाएँ, घर पर पढ़ाई से जुड़ा संवाद और निरीक्षण विद्यार्थियों के अध्ययन-व्यवहार को सीधे दिशा देते हैं। हिल और टायसन (2009) का निष्कर्ष कि शैक्षिक समाजीकरण प्रत्यक्ष गृहकार्य-सहायता से अधिक प्रभावी है, यहाँ भी प्रासंगिक लगता है। इस मापनी में संवाद और अपेक्षाओं से जुड़े कथनों का भार अधिक था।

विद्यालयी सामाजिक पूंजी का सार्थक योगदान (β = .24) क्रोनिंजर और ली (2001) तथा स्टैंटन-सालाज़ार (2011) के निष्कर्षों का समर्थन

करता है। शिक्षक केवल ज्ञान के संप्रेषक नहीं, बल्कि संस्थागत अभिकर्ता भी हैं जो विद्यार्थियों को मार्गदर्शन और अवसरों से जोड़ते हैं। सहपाठी नेटवर्क का प्रभाव सार्थक होते हुए भी अपेक्षाकृत कम रहा। इससे संकेत मिलता है कि मित्र-समूह का शैक्षिक लाभ इस पर निर्भर करता है कि उस समूह के मानक अध्ययन-केंद्रित हैं या नहीं।

सामुदायिक सामाजिक पूंजी का बहुचर मॉडल में असार्थक होना एक रोचक निष्कर्ष है। इसका द्विचर सहसंबंध सार्थक था (r = .29), पर इसका अधिकांश प्रभाव संभवतः परिवार और सहपाठी नेटवर्क के माध्यम से अप्रत्यक्ष रूप से पहुँचता है। तालिका 3 में सामुदायिक पूंजी का सहपाठी नेटवर्क (r = .45) और पारिवारिक पूंजी (r = .39) से सहसंबंध इस व्याख्या का समर्थन करता है। पोर्टेस (1998) की यह चेतावनी भी प्रासंगिक है कि सामुदायिक संबंध सदैव शैक्षिक लाभ में नहीं बदलते।

शहरी-ग्रामीण अंतर देसाई और कुलकर्णी (2008) द्वारा बताई गई संरचनात्मक असमानताओं की ओर संकेत करता है। बोर्दियो (1986) के दृष्टिकोण से, सामाजिक पूंजी तक असमान पहुँच शैक्षिक असमानता के पुनरुत्पादन का एक माध्यम बनती है। ग्रामीण विद्यार्थियों में अभिभावकों की सीमित शिक्षा, शिक्षकों से कम संपर्क और शैक्षिक सूचना-नेटवर्क की कमी इस अंतर के संभावित कारण हो सकते हैं।

शैक्षिक निहितार्थ

1. विद्यालयों को अभिभावक-शिक्षक संवाद को नियमित और संरचित बनाना चाहिए, जिसमें शैक्षिक अपेक्षाओं और भविष्य की योजनाओं पर चर्चा हो।

2. शिक्षकों के प्रशिक्षण में विद्यार्थियों से सहयोगी और मार्गदर्शक संबंध बनाने के कौशल शामिल किए जाने चाहिए।

3. सहकर्मी अधिगम और संरचित अध्ययन-समूहों को प्रोत्साहित करना चाहिए ताकि सहपाठी नेटवर्क अध्ययन-केंद्रित बनें।

4. ग्रामीण विद्यालयों में अभिभावक-जागरूकता कार्यक्रम, परामर्श सेवाएँ और मेंटरशिप योजनाएँ प्राथमिकता से लागू की जानी चाहिए।

5. सामुदायिक सहभागिता कार्यक्रमों को सीधे शैक्षिक लक्ष्यों से जोड़ा जाना चाहिए ताकि उनका लाभ उपलब्धि में बदल सके।

सीमाएँ एवं भावी शोध के सुझाव

यह अध्ययन अनुप्रस्थ (cross-sectional) अभिकल्प पर आधारित है, इसलिए कारण-कार्य संबंध स्थापित नहीं किए जा सकते। प्रतिदर्श उत्तर प्रदेश के दो जनपदों तक सीमित है, जिससे परिणामों का सामान्यीकरण सीमित होता है। सामाजिक पूंजी का मापन स्व-प्रतिवेदन पर आधारित था, जिसमें सामाजिक वांछनीयता का प्रभाव संभव है। इस अध्ययन में सामाजिक-आर्थिक स्थिति को नियंत्रक चर के रूप में शामिल नहीं किया गया। भावी शोध में अनुदैर्ध्य अभिकल्प, संरचनात्मक समीकरण मॉडलिंग के माध्यम से मध्यस्थता-विश्लेषण, सामाजिक-आर्थिक स्थिति का नियंत्रण और विभिन्न राज्यों के बड़े प्रतिदर्श अपनाए जा सकते हैं।

निष्कर्ष

यह अध्ययन दिखाता है कि सामाजिक पूंजी माध्यमिक विद्यार्थियों की शैक्षिक उपलब्धि का एक सार्थक और प्रबल निर्धारक है। इसके चारों आयाम मिलकर उपलब्धि के लगभग एक-तिहाई प्रसरण की व्याख्या करते हैं। पारिवारिक सामाजिक पूंजी सबसे प्रभावी है, उसके बाद विद्यालयी सामाजिक पूंजी और सहपाठी नेटवर्क आते हैं। सामुदायिक सामाजिक पूंजी का प्रभाव मुख्यतः अप्रत्यक्ष प्रतीत होता है। उच्च सामाजिक पूंजी वाले विद्यार्थियों ने निम्न सामाजिक पूंजी वाले विद्यार्थियों से लगभग 19 प्रतिशत अंक अधिक प्राप्त किए। शहरी और ग्रामीण विद्यार्थियों के बीच सामाजिक पूंजी का अंतर शैक्षिक असमानता का एक महत्त्वपूर्ण आयाम है। अतः शैक्षिक सुधार की नीतियों में संसाधनों के साथ-साथ सामाजिक संबंधों के सुदृढ़ीकरण को भी केंद्र में रखना आवश्यक है।

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अध्याय 43: कृत्रिम बुद्धिमत्ता के बढ़ते उपयोग से युवाओं के सामाजिक व्यवहार में परिवर्तन

निधि सैनी
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समाजशास्त्र विभाग
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शोध सार—प्रस्तुत अध्ययन इस प्रश्न की पड़ताल करता है कि कृत्रिम बुद्धिमत्ता आधारित उपकरणों के बढ़ते दैनिक उपयोग से युवाओं के सामाजिक व्यवहार में किस प्रकार का परिवर्तन हो रहा है। अध्ययन का केंद्रीय तर्क यह है कि परिवर्तन की दिशा उपयोग की मात्रा से नहीं, अपितु उपयोग के प्रयोजन से निर्धारित होती है — कार्य-सहायक प्रयोजन तथा संबंध-प्रतिस्थापी प्रयोजन के परिणाम परस्पर विपरीत दिशाओं में जाते हैं। अठारह से पचीस वर्ष आयु वर्ग के 540 युवाओं से आँकड़े एकत्र कर सहसंबंध, प्रसरण विश्लेषण, बहुचर समाश्रयण तथा मध्यस्थता विश्लेषण किए गए। परिणामों में यह पाया गया कि कार्य-सहायक उपयोग का आमने-सामने की सामाजिक सक्रियता से संबंध नगण्य है, जबकि संबंध-प्रतिस्थापी उपयोग का संबंध सामाजिक परिहार एवं संवाद-सहजता के ह्रास से प्रबल रूप से जुड़ा है। साथ ही स्वायत्त निर्णय-क्षमता पर निर्भरता का प्रभाव संज्ञानात्मक सौंपन के माध्यम से संचालित पाया गया। निष्कर्ष यह है कि कृत्रिम बुद्धिमत्ता स्वयं में सामाजिक व्यवहार की क्षयकारी शक्ति नहीं है, किंतु जब वह मानवीय संपर्क का विकल्प बनने लगती है, तब उसका प्रभाव उल्लेखनीय रूप से ऋणात्मक हो जाता है।

बीज शब्द—कृत्रिम बुद्धिमत्ता, सामाजिक व्यवहार, युवा, संज्ञानात्मक सौंपन, संबंध-प्रतिस्थापन, मानव-मशीन अंतःक्रिया

प्रस्तावना

विगत कुछ वर्षों में कृत्रिम बुद्धिमत्ता आधारित उपकरण युवाओं के दैनिक जीवन का सामान्य अंग बन गए हैं। संवादी सहायकों से प्रश्न पूछना, लेखन में सहायता लेना, पाठ्य-सामग्री का सारांश निकलवाना, निर्णय के विकल्पों पर परामर्श माँगना तथा अकेलेपन के क्षणों में केवल बातचीत के लिए इन उपकरणों की ओर मुड़ना — ये सब अब असामान्य व्यवहार नहीं रह गए हैं।

यह परिवर्तन पूर्ववर्ती प्रौद्योगिकीय परिवर्तनों से एक महत्वपूर्ण दृष्टि से भिन्न है। सोशल मीडिया ने मानवीय संप्रेषण का माध्यम बदला था, किंतु दूसरा छोर मनुष्य ही रहता था। कृत्रिम बुद्धिमत्ता के संवादी उपकरणों में दूसरा छोर मनुष्य नहीं है, फिर भी अंतःक्रिया का अनुभव संवाद जैसा ही है। यह वह स्थिति है जिसके लिए मानव-समाज के पास पूर्व-अनुभव नहीं है।

इससे कई प्रश्न उठते हैं। जब कोई युवा किसी दुविधा में मित्र से परामर्श लेने के स्थान पर मशीन से परामर्श लेता है, तो क्या वह केवल साधन बदल रहा है अथवा उस सामाजिक संबंध का अभ्यास भी छोड़ रहा है जो परामर्श माँगने से बनता था? जब लेखन, विश्लेषण एवं निर्णय के कार्य बाह्य रूप से संपन्न होने लगते हैं, तो क्या स्वतंत्र चिंतन का अभ्यास क्षीण होता है? और क्या इन प्रभावों को सभी उपयोगकर्ताओं के लिए समान माना जा सकता है, अथवा उपयोग की प्रकृति निर्णायक है? प्रस्तुत अध्ययन इन्हीं प्रश्नों का अनुभवजन्य परीक्षण करता है।



सैद्धांतिक ढाँचा

अध्ययन तीन सैद्धांतिक स्रोतों पर आधारित है। प्रथम, रीव्स एवं नास (1996) का 'मीडिया समीकरण' सिद्धांत, जिसके अनुसार मनुष्य संचार-माध्यमों एवं संगणकों के प्रति अनजाने ही वैसी ही सामाजिक प्रतिक्रियाएँ प्रदर्शित करते हैं जैसी वास्तविक व्यक्तियों के प्रति। यह सिद्धांत यह समझने का आधार देता है कि संवादी कृत्रिम बुद्धिमत्ता के साथ की गई अंतःक्रिया मनोवैज्ञानिक रूप से सामाजिक अंतःक्रिया जैसी क्यों अनुभूत होती है।

द्वितीय, स्पैरो, लियू एवं वेगनर (2011) का संव्यवहारात्मक स्मृति संबंधी कार्य, जिसमें उन्होंने प्रदर्शित किया कि जब सूचना की बाह्य उपलब्धता सुनिश्चित होती है, तो व्यक्ति उस सूचना को स्मरण रखने के स्थान पर उसके स्रोत को स्मरण रखता है। इस अंतर्दृष्टि का विस्तार करते हुए प्रस्तुत अध्ययन 'संज्ञानात्मक सौंपन' को एक मध्यस्थ चर के रूप में प्रयुक्त करता है।

तृतीय, टर्कल (2011) का विश्लेषण, जिसमें उन्होंने यह तर्क दिया कि प्रौद्योगिकी जुड़ाव की सुविधा तो बढ़ाती है किंतु गहन मानवीय संबंध की अपेक्षाओं को कम भी कर देती है — मनुष्य 'एक साथ किंतु अकेले' होते जाते हैं। इन तीनों को जोड़ने पर वह ढाँचा बनता है जिसमें कृत्रिम बुद्धिमत्ता का प्रभाव प्रयोजन-सापेक्ष एवं क्रियाविधि-आधारित रूप में देखा जा सकता है।

पूर्ववर्ती अध्ययनों की समीक्षा

मानव एवं संगणक की अंतःक्रिया को सामाजिक प्रतिक्रिया के रूप में देखने की परंपरा नास, स्टीयर एवं टॉबर (1994) के प्रयोगों से आरंभ होती है, जिन्होंने यह दर्शाया कि उपयोगकर्ता संगणकों को सामाजिक कर्ता के रूप में ग्रहण करते हैं। नास एवं मून (2000) ने इसे और स्पष्ट करते हुए बताया कि यह प्रतिक्रिया अनजाने में घटित होती है और उपयोगकर्ता इसे स्वीकार करने में संकोच करते हैं। इस परंपरा का सबसे आधुनिक विस्तार गैंबिनो, फॉक्स एवं रैटन (2020) का संशोधित प्रतिमान है, जिसमें उन्होंने यह तर्क दिया कि उपयोगकर्ता अब मानव-मानदंडों के स्थान पर माध्यम-विशिष्ट मानदंडों का प्रयोग करने लगे हैं।

संबंध-प्रतिस्थापन के प्रश्न पर क्रॉट एवं सहयोगियों (1998) का प्रारंभिक कार्य महत्वपूर्ण है, जिसमें इंटरनेट उपयोग एवं सामाजिक संलग्नता के बीच ऋणात्मक संबंध पाया गया था, यद्यपि क्रॉट एवं सहयोगियों (2002) के परवर्ती अनुवर्तन में यह प्रभाव क्षीण अथवा उलट पाया गया। इस विरोधाभास का समाधान उपयोग-प्रकार के भेद में निहित है, जिसे वर्दुइन एवं सहयोगियों (2017) ने सक्रिय-निष्क्रिय भेद द्वारा तथा वैलेनबर्ग एवं पीटर (2007) ने संप्रेषण-साथी के भेद द्वारा स्पष्ट किया। प्रस्तुत अध्ययन का प्रयोजन-आधारित वर्गीकरण इसी पद्धतिगत परंपरा का विस्तार है।

संज्ञानात्मक प्रभावों के संदर्भ में स्पैरो एवं सहयोगियों (2011) के अतिरिक्त बार, पेनीकुक एवं फ्यूजेल्सांग (2015) का कार्य उल्लेखनीय है, जिन्होंने यह दर्शाया कि जो व्यक्ति सहज-सज्ञानात्मक शैली के होते हैं, वे उपकरणों पर अधिक निर्भरता प्रदर्शित करते हैं, और यह निर्भरता स्वतंत्र विश्लेषणात्मक चिंतन के अभ्यास को घटाती है। रीज एवं सहयोगियों (2019) ने प्रौद्योगिकी-उपयोग एवं मनोवैज्ञानिक कल्याण संबंधी साक्ष्यों की समीक्षा प्रस्तुत करते हुए पद्धतिगत सावधानियों को रेखांकित किया।

कृत्रिम बुद्धिमत्ता की सामाजिक स्वीकार्यता के संदर्भ में लॉन्गोनी, बोनेज़ी एवं मोर्वित्ज़ (2019) ने यह दर्शाया कि व्यक्ति संवेदनशील क्षेत्रों में एल्गोरिद्मीय परामर्श के प्रति अनिच्छा प्रकट करते हैं, जबकि लॉजिस, डेलाहेज एवं सिम्मन्स (2019) ने एल्गोरिद्म-अनिच्छा के न्यूनीकरण की परिस्थितियों का परीक्षण किया। डिएत्वोर्स्ट, सिम्मन्स एवं मैसी (2015) ने यह प्रसिद्ध निष्कर्ष प्रस्तुत किया कि एल्गोरिद्म की एक त्रुटि देखने के उपरांत व्यक्ति उस पर से विश्वास शीघ्रता से हटा लेते हैं, जबकि मनुष्य की समान त्रुटि के प्रति वे अधिक सहिष्णु रहते हैं। शैक्षिक संदर्भ में जेंग, मा एवं वांग (2021) ने कृत्रिम बुद्धिमत्ता आधारित संवादी सहायकों के अधिगम-परिणामों पर प्रभाव का मेटा-विश्लेषण प्रस्तुत किया।

भारतीय एवं वैश्विक नीतिगत संदर्भ में यूनेस्को (2021) की कृत्रिम बुद्धिमत्ता की नैतिकता संबंधी अनुशंसा युवाओं पर पड़ने वाले सामाजिक प्रभावों के मूल्यांकन को नीतिगत प्राथमिकता के रूप में स्थापित करती है। यूनेस्को (2023) की वैश्विक शिक्षा निगरानी रिपोर्ट ने शिक्षा में प्रौद्योगिकी के उपयोग का समीक्षात्मक आकलन प्रस्तुत किया। राष्ट्रीय शिक्षा नीति 2020 ने कृत्रिम बुद्धिमत्ता संबंधी जागरूकता एवं इसके नैतिक आयामों को पाठ्यक्रम का अंग बनाने की संस्तुति की है, तथा भारतीय दूरसंचार नियामक प्राधिकरण (2023) के आँकड़े उस डिजिटल आधार-संरचना की व्यापकता दर्शाते हैं जिस पर यह उपयोग टिका है।

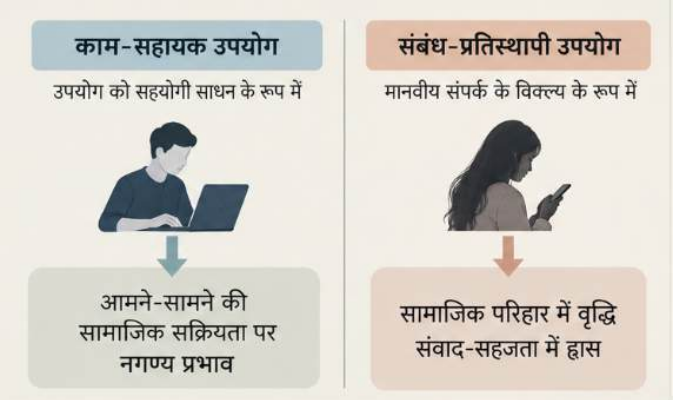
शोध अंतराल

समीक्षा से दो रिक्तियाँ स्पष्ट होती हैं। प्रथम, कृत्रिम बुद्धिमत्ता संबंधी अधिकांश अनुभवजन्य कार्य स्वीकार्यता, विश्वास एवं अधिगम-परिणामों तक सीमित है; सामाजिक व्यवहार में होने वाले परिवर्तन का व्यवस्थित मात्रात्मक मापन अत्यल्प हुआ है। द्वितीय, जहाँ अध्ययन हुए भी हैं, वहाँ उपयोग को एकाकी चर माना गया है, जिससे यह पता नहीं चलता कि विभिन्न प्रयोजनों के प्रभाव भिन्न-भिन्न हैं अथवा नहीं। भारतीय युवा-संदर्भ में यह रिक्ति और भी अधिक है। प्रस्तुत अध्ययन इन्हें संबोधित करता है।

उद्देश्य एवं उपकल्पनाएँ

उद्देश्य हैं — युवाओं में कृत्रिम बुद्धिमत्ता के उपयोग का प्रयोजन-आधारित वर्गीकरण एवं मापन; सामाजिक व्यवहार के तीन आयामों का मापन; उपयोग-प्रयोजनों एवं व्यवहार-आयामों के मध्य संबंध का परीक्षण; तथा संज्ञानात्मक सौंपन की मध्यस्थ भूमिका का आकलन।

शून्य उपकल्पनाएँ — दैनिक उपयोग-अवधि एवं सामाजिक सक्रियता के मध्य सार्थक संबंध नहीं है; विभिन्न प्रयोजन-समूहों के सामाजिक व्यवहार में सार्थक अंतर नहीं है; संबंध-प्रतिस्थापी उपयोग सामाजिक परिहार का सार्थक पूर्वानुमानक नहीं है; तथा स्वायत्त निर्णय-क्षमता एवं उपयोग के संबंध में संज्ञानात्मक सौंपन का मध्यस्थ प्रभाव सार्थक नहीं है।



शोध प्रविधि

अध्ययन में वर्णनात्मक सर्वेक्षण अभिकल्प अपनाया गया। जनसंख्या में महाविद्यालयों, विश्वविद्यालय विभागों तथा प्रारंभिक व्यावसायिक कार्यक्षेत्रों से जुड़े अठारह से पचीस वर्ष आयु वर्ग के वे युवा सम्मिलित थे जो किसी न किसी रूप में कृत्रिम बुद्धिमत्ता आधारित उपकरण का प्रयोग करते हैं। उद्देश्यपूर्ण-सह-कोटा निदर्शन द्वारा लिंग, आयु-उपवर्ग एवं शैक्षिक-व्यावसायिक स्थिति का अनुपात संतुलित रखा गया। कुल 600 प्रश्नावलियाँ वितरित की गईं, जिनमें से 540 पूर्ण एवं विश्लेषण-योग्य प्राप्त हुईं (प्रत्युत्तर दर 90.0 प्रतिशत)।

मापन हेतु चार खंडों की प्रश्नावली विकसित की गई। *उपयोग-प्रयोजन मापनी* में तीन उपमापनियाँ थीं — कार्य-सहायक उपयोग (अध्ययन, लेखन, सारांशन), सूचना-निर्भर उपयोग (तथ्य-प्राप्ति, स्पष्टीकरण) तथा

संबंध-प्रतिस्थापी उपयोग (मनोभाव साझा करना, अकेलेपन में संवाद, परामर्श) — प्रत्येक में पाँच कथन। *सामाजिक व्यवहार मापनी* में तीन आयाम थे — आमने-सामने सामाजिक सक्रियता, संवाद-सहजता तथा सामाजिक परिहार — प्रत्येक में छह कथन। तृतीय खंड में संज्ञानात्मक सौंपन संबंधी सात कथन तथा चतुर्थ खंड में स्वायत्त निर्णय-क्षमता संबंधी छह कथन थे। सभी कथन पाँच-बिंदु मापनी पर अंकित थे तथा प्राप्तांक शून्य से सौ की श्रेणी में रूपांतरित किए गए।

अंतर्वस्तु वैधता हेतु मनोविज्ञान, समाजशास्त्र एवं संगणक विज्ञान के आठ विशेषज्ञों से परामर्श लिया गया तथा पचासी उत्तरदाताओं पर पूर्व-परीक्षण किया गया। विश्लेषण में पीयर्सन सहसंबंध, एकमार्गी प्रसरण विश्लेषण, ट्यूकी उत्तर-परीक्षण, बहुचर समाश्रयण तथा पुनःप्रतिचयन आधारित मध्यस्थता परीक्षण प्रयुक्त हुए। पूर्वधारणा-परीक्षण में विषमता एवं ककुदता ±1 के भीतर रहीं, लीवीन परीक्षण असार्थक रहा ($p = 0.26$) तथा प्रसरण-स्फीति गुणक का अधिकतम मान 2.19 पाया गया।

नैतिक विचार

समस्त प्रतिभागियों से सूचित सहमति ली गई, प्रतिभागिता स्वैच्छिक रही तथा कोई व्यक्तिगत पहचान-योग्य सूचना संकलित नहीं की गई। किसी भी प्रतिभागी के संवाद-अभिलेख अथवा उपकरण-इतिहास तक पहुँच नहीं बनाई गई।

तालिका एक — उत्तरदाताओं का विवरण (न = 540)

आधार	उपवर्ग	न	प्रतिशत
लिंग	पुरुष / महिला	275 / 265	50.9 / 49.1
आयु	18–21 / 22–25	259 / 281	48.0 / 52.0
स्थिति	विद्यार्थी / कार्यरत	341 / 199	63.1 / 36.9
दैनिक उपयोग	30 मिनट तक	146	27.0
	30 मिनट – 2 घंटे	243	45.0
	2 घंटे से अधिक	151	28.0
उपयोग-अनुभव	एक वर्ष तक / एक वर्ष से अधिक	201 / 339	37.2 / 62.8

परिणाम

तालिका दो — चरों का वर्णनात्मक विवरण एवं विश्वसनीयता

चर	औसत	मा.वि.	अल्फा
कार्य-सहायक उपयोग	64.8	18.2	0.86
सूचना-निर्भर उपयोग	59.3	17.6	0.83
संबंध-प्रतिस्थापी उपयोग	31.7	21.4	0.88
आमने-सामने सामाजिक सक्रियता	58.6	17.8	0.84
संवाद-सहजता	61.2	18.1	0.85
सामाजिक परिहार	39.4	19.6	0.87
संज्ञानात्मक सौंपन	52.9	19.3	0.85
स्वायत्त निर्णय-क्षमता	57.4	17.5	0.82

संबंध-प्रतिस्थापी उपयोग का औसत (31.7) अन्य दोनों प्रयोजनों से स्पष्ट रूप से कम है, अर्थात् बहुसंख्य युवा इन उपकरणों का प्रयोग मुख्यतः कार्य एवं सूचना के लिए करते हैं। किंतु इस चर का मानक विचलन सर्वाधिक (21.4) है, जो यह दर्शाता है कि एक अल्पसंख्यक वर्ग इसका प्रयोग उल्लेखनीय रूप से अधिक कर रहा है।

तालिका तीन — उपयोग-प्रयोजन एवं सामाजिक व्यवहार के मध्य सहसंबंध

उपयोग प्रयोजन	सामाजिक सक्रियता	संवाद-सहजता	सामाजिक परिहार	संज्ञानात्मक सौंपन
कार्य-सहायक	0.08	0.11	−0.06	0.34
सूचना-निर्भर	−0.05	0.04	0.09	0.41
संबंध-प्रतिस्थापी	−0.42	−0.47	0.53	0.38

दैनिक उपयोग-अवधि	**–0.12**	**–0.09**	**0.14**	**0.27**

0.14 से अधिक निरपेक्ष मान $p < 0.01$ पर सार्थक; 0.11 एवं 0.12 $p < 0.05$ पर; 0.04 से 0.09 तक असार्थक

यह तालिका अध्ययन का केंद्रीय निष्कर्ष प्रस्तुत करती है। कार्य-सहायक एवं सूचना-निर्भर उपयोग का सामाजिक व्यवहार के तीनों आयामों से संबंध नगण्य है, जबकि संबंध-प्रतिस्थापी उपयोग का संबंध तीनों से प्रबल एवं अपेक्षित दिशा में है। दैनिक उपयोग-अवधि का संबंध अत्यंत दुर्बल पाया गया — यद्यपि सामाजिक परिहार के साथ वह तकनीकी रूप से सार्थक है (0.14), उसका व्यावहारिक परिमाण नगण्य है। इस प्रकार प्रथम शून्य उपकल्पना अस्वीकृत तो होती है, किंतु निष्कर्ष यह है कि अवधि सामाजिक व्यवहार-परिवर्तन का सार्थक सूचक नहीं है।

तालिका चार — प्रभावी उपयोग-प्रयोजन के अनुसार समूह-भिन्नता

प्रभावी प्रयोजन	**न**	**प्रतिशत**	**सामाजिक सक्रियता**	**संवाद-सहजता**	**सामाजिक परिहार**
कार्य-प्रधान	236	43.7	62.4	66.1	33.8
सूचना-प्रधान	187	34.6	59.7	61.4	37.9
प्रतिस्थापन-प्रधान	117	21.7	50.2	51.6	52.7
समग्र	**540**	**100.0**	**58.6**	**61.2**	**39.4**

सामाजिक सक्रियता: $F\ (2, 537) = 22.86$, $p < 0.001$, $\eta^2 = 0.08$
संवाद-सहजता: $F\ (2, 537) = 32.71$, $p < 0.001$, $\eta^2 = 0.11$
सामाजिक परिहार: $F\ (2, 537) = 48.19$, $p < 0.001$, $\eta^2 = 0.15$

तीनों आयामों पर समूह-भिन्नता सार्थक पाई गई, अतः द्वितीय शून्य उपकल्पना अस्वीकृत हुई। ट्यूकी उत्तर-परीक्षण में प्रतिस्थापन-प्रधान समूह का अंतर शेष दोनों समूहों से तीनों आयामों पर सार्थक रहा ($p < 0.001$), जबकि कार्य-प्रधान एवं सूचना-प्रधान समूहों के बीच सामाजिक सक्रियता का अंतर असार्थक पाया गया। अर्थात् वास्तविक विभाजक रेखा प्रतिस्थापन-प्रधान उपयोग के इर्द-गिर्द खिंचती है, अन्यत्र नहीं।

तालिका पाँच — सामाजिक परिहार का बहुचर समाश्रयण विश्लेषण

पूर्वानुमानक चर	**B**	**मानक त्रुटि**	**β**	**t**	**सार्थकता**
संबंध-प्रतिस्थापी उपयोग	0.44	0.04	0.48	12.14	$p < 0.001$
संज्ञानात्मक सौंपन	0.16	0.04	0.16	3.86	$p < 0.001$
कार्य-सहायक उपयोग	–0.08	0.05	–0.07	–1.73	असार्थक
सूचना-निर्भर उपयोग	0.06	0.05	0.05	1.28	असार्थक
दैनिक उपयोग-अवधि	0.51	0.61	0.03	0.84	असार्थक
लिंग	–1.28	1.44	–0.03	–0.89	असार्थक
आयु	–0.34	0.28	–0.05	–1.21	असार्थक

$R^2 = 0.33$, समायोजित $R^2 = 0.32$, $F\ (7, 532) = 37.42$, $p < 0.001$

संबंध-प्रतिस्थापी उपयोग सर्वाधिक प्रबल पूर्वानुमानक सिद्ध हुआ, अतः तृतीय शून्य उपकल्पना अस्वीकृत हुई। उपयोग-अवधि का गुणांक पुनः असार्थक रहा, जो प्रयोजन-आधारित व्याख्या को दृढ़ता प्रदान करता है।

तालिका छह — मध्यस्थता विश्लेषण के पथ गुणांक (परिणाम-चर: स्वायत्त निर्णय-क्षमता)

पथ	**विवरण**	**β**	**मानक त्रुटि**	**t / विश्वास अंतराल**
a	सूचना-निर्भर उपयोग → संज्ञानात्मक सौंपन	0.41	0.04	10.42 ($p < 0.001$)
b	संज्ञानात्मक सौंपन → निर्णय-क्षमता	–0.37	0.04	–8.96 ($p < 0.001$)

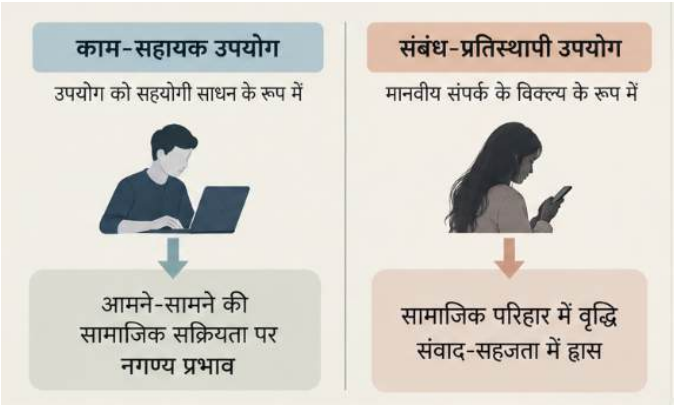
c	कुल प्रभाव	−0.24	0.04	−5.72 (p < 0.001)
c′	प्रत्यक्ष प्रभाव	−0.09	0.04	−2.11 (p < 0.05)
a×b	अप्रत्यक्ष प्रभाव	−0.15	0.03	−0.21 से −0.09

प्रतिमान: $R^2 = 0.19$, $F(2, 537) = 62.98$, $p < 0.001$

अप्रत्यक्ष प्रभाव का विश्वास अंतराल शून्य को सम्मिलित नहीं करता, अतः चतुर्थ शून्य उपकल्पना अस्वीकृत हुई। कुल प्रभाव का लगभग 63 प्रतिशत भाग संज्ञानात्मक सौंपन के माध्यम से संचालित पाया गया — अर्थात् मध्यस्थता प्रबल एवं आंशिक है।

विवेचन

अध्ययन का समग्र निष्कर्ष यह है कि कृत्रिम बुद्धिमत्ता का सामाजिक व्यवहार पर प्रभाव उपकरण की विशेषता नहीं, अपितु उपयोगकर्ता के प्रयोजन की विशेषता है। जो युवा इसे कार्य-सहायक के रूप में प्रयोग करते हैं, उनके सामाजिक व्यवहार में कोई उल्लेखनीय अंतर नहीं दिखाई देता; जो इसे मानवीय संपर्क के विकल्प के रूप में प्रयोग करते हैं, उनमें परिवर्तन स्पष्ट एवं एक-दिशीय है। यह प्रतिरूप क्रॉट एवं सहयोगियों (1998, 2002) के परस्पर-विरोधी निष्कर्षों को भी समाधान प्रदान करता है — विरोधाभास तब समाप्त हो जाता है जब उपयोग को प्रयोजन के आधार पर विभेदित किया जाए, जैसा वैलेनबर्ग एवं पीटर (2007) तथा वर्दुइन एवं सहयोगियों (2017) ने संकेत किया था।



संबंध-प्रतिस्थापी उपयोग एवं सामाजिक परिहार का प्रबल संबंध (0.53) टर्कल (2011) की उस चिंता की अनुभवजन्य पुष्टि करता है कि सुविधाजनक अंतःक्रिया गहन मानवीय संबंध की अपेक्षा को कम कर देती है। यहाँ कारण-दिशा का प्रश्न महत्वपूर्ण है — यह भी संभव है कि जो युवा पहले से सामाजिक परिहार की प्रवृत्ति रखते हैं, वे ही इन उपकरणों की ओर संबंध-प्रतिस्थापी प्रयोजन से मुड़ते हों। दोनों संभावनाएँ परस्पर अपवर्जी नहीं हैं और संभवतः एक आत्म-प्रबलक चक्र का निर्माण करती हैं, जिसमें परिहार प्रतिस्थापन को और प्रतिस्थापन परिहार को बढ़ाता है।

रीव्स एवं नास (1996) तथा नास एवं मून (2000) का ढाँचा यह समझाने में सहायक है कि यह प्रतिस्थापन मनोवैज्ञानिक रूप से संभव क्यों है — यदि उपयोगकर्ता मशीन के प्रति अनजाने ही सामाजिक प्रतिक्रियाएँ देता है, तो वह अंतःक्रिया आंशिक रूप से सामाजिक आवश्यकता की पूर्ति कर सकती है, बिना उस आवश्यकता को वास्तव में संतुष्ट किए।

संज्ञानात्मक सौंपन के माध्यम से संचालित मध्यस्थता स्पैरो एवं सहयोगियों (2011) के निष्कर्षों का तार्किक विस्तार है। सूचना-निर्भर उपयोग स्वयं में सामाजिक व्यवहार को प्रभावित नहीं करता, किंतु वह उस मनोवैज्ञानिक अभ्यास को बदलता है जिसके द्वारा व्यक्ति स्वयं निष्कर्ष तक पहुँचता है। बार एवं सहयोगियों (2015) का यह प्रेक्षण भी प्रासंगिक है कि सौंपन की प्रवृत्ति व्यक्तित्वगत भिन्नताओं से जुड़ी है, अतः इसका प्रभाव सभी पर समान नहीं होगा।



निहितार्थ

निष्कर्ष सार्वजनिक विमर्श में एक सुधार की माँग करते हैं। 'उपयोग घटाइए' का सामान्य परामर्श इन आँकड़ों से समर्थित नहीं होता, क्योंकि उपयोग-अवधि का पूर्वानुमानक मूल्य नगण्य पाया गया। इसके स्थान पर तीन दिशाएँ अधिक उपयुक्त हैं। प्रथम, शैक्षिक संस्थानों में कृत्रिम बुद्धिमत्ता साक्षरता के पाठ्यक्रमों को केवल तकनीकी कौशल तक सीमित न रखकर उपयोग-प्रयोजन की सजगता तक विस्तारित करना। द्वितीय, महाविद्यालय स्तर पर परामर्श एवं सहकर्मी-सहायता व्यवस्थाओं को सुदृढ़ करना, जिससे भावनात्मक आवश्यकता के क्षणों में मानवीय विकल्प सहज उपलब्ध रहे — क्योंकि प्रतिस्थापन प्रायः विकल्प के अभाव में ही होता है। तृतीय, अकादमिक कार्यों में ऐसे मूल्यांकन-प्रारूपों का विकास जो स्वतंत्र विश्लेषण के अभ्यास को सुरक्षित रखें, जिससे संज्ञानात्मक सौंपन का मार्ग संतुलित रहे।

सीमाएँ

अध्ययन अनुप्रस्थ-काटीय है, अतः कारण-दिशा निर्धारित नहीं की जा सकती। समस्त आँकड़े स्व-कथन पर आधारित हैं तथा उपयोग-अवधि का अनुमान वास्तविक अभिलेखों से भिन्न हो सकता है। निदर्शन उद्देश्यपूर्ण-सह-कोटा प्रकृति का है, पूर्णतः प्रायिकता-आधारित नहीं। उपकरण-विशिष्ट भिन्नताओं का पृथक् विश्लेषण नहीं किया गया तथा व्यक्तित्व-चर एवं पूर्ववर्ती सामाजिक प्रवृत्ति प्रतिमान में सम्मिलित नहीं थे, जो चयन-प्रभाव की संभावना को खुला छोड़ते हैं।

भावी शोध दिशाएँ

अनुदैर्घ्य अभिकल्प द्वारा यह परीक्षण अनिवार्य है कि प्रतिस्थापन-प्रधान उपयोग परिहार का कारण है अथवा परिणाम। व्यक्तित्व-चरों को नियंत्रित करने वाला विस्तृत प्रतिमान चयन-प्रभाव को पृथक् कर सकेगा। प्रयोगात्मक अभिकल्प द्वारा संज्ञानात्मक सौंपन के अल्पकालिक प्रभावों का परीक्षण, तथा गुणात्मक साक्षात्कार द्वारा यह

अन्वेषण कि युवा किन विशिष्ट परिस्थितियों में मानवीय संपर्क के स्थान पर मशीन की ओर मुड़ते हैं, इस क्षेत्र को महत्वपूर्ण गहराई प्रदान करेगा।

निष्कर्ष

प्रस्तुत अध्ययन यह स्थापित करता है कि कृत्रिम बुद्धिमत्ता के बढ़ते उपयोग का युवाओं के सामाजिक व्यवहार पर प्रभाव एकांगी अथवा अनिवार्य रूप से क्षयकारी नहीं है। कार्य-सहायक एवं सूचना-निर्भर उपयोग सामाजिक व्यवहार को उल्लेखनीय रूप से प्रभावित नहीं करते; किंतु जब उपयोग मानवीय संपर्क का स्थान लेने लगता है, तब सामाजिक परिहार बढ़ता है और संवाद-सहजता घटती है। समानांतर रूप से, सूचना-निर्भर उपयोग स्वायत्त निर्णय-क्षमता को संज्ञानात्मक सौंपन के माध्यम से अप्रत्यक्ष रूप से क्षीण करता है। इससे यह निष्कर्ष निकलता है कि चिंता का उचित केंद्र प्रौद्योगिकी नहीं, अपितु वह रिक्तता है जिसे प्रौद्योगिकी भरने लगती है। जहाँ मानवीय संपर्क एवं स्वतंत्र चिंतन के अवसर सुरक्षित रहेंगे, वहाँ कृत्रिम बुद्धिमत्ता सहायक उपकरण बनी रहेगी; जहाँ वे अवसर क्षीण होंगे, वहीं वह विकल्प बनकर सामाजिक व्यवहार को पुनर्गठित करेगी।

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