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SUSTAINABLE
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VIKSIT BHARAT

PART

2

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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.

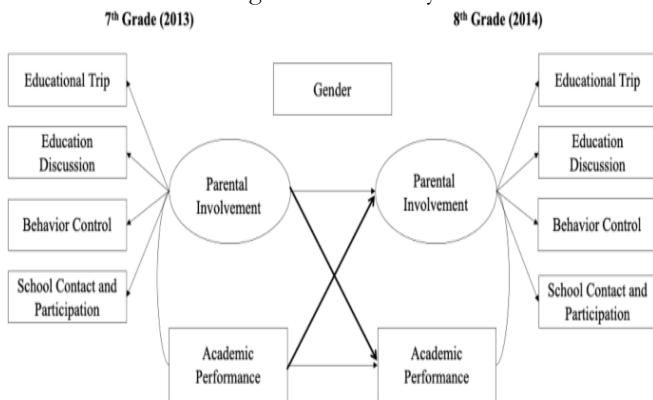


Fig. 1: Reciprocal Relationships Between Parental Involvement and Academic Performance in Early Adolescence

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.

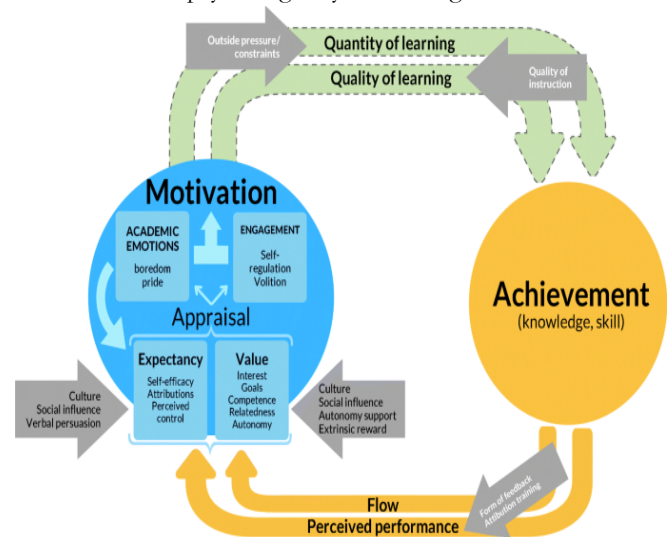


Fig. 2: Motivation-Achievement Cycles in Learning

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 Fatımaningrum (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**.

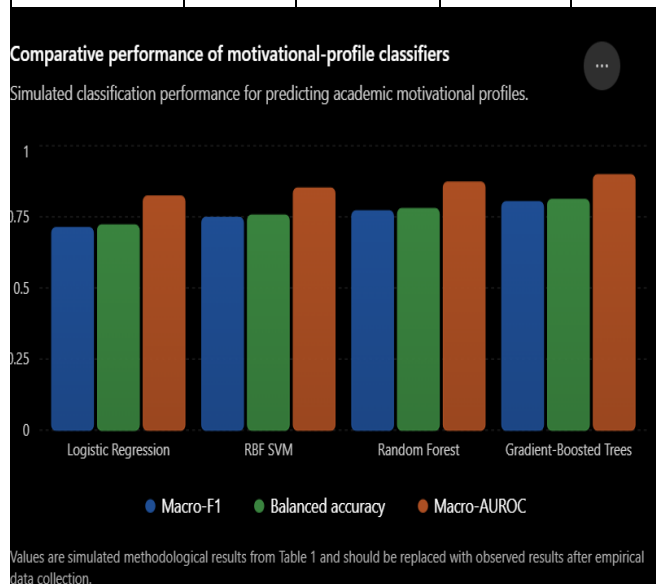
Adolescents assigned to the autonomy-supportive profile demonstrated the highest simulated autonomous-motivation scores. Connected monitoring was associated with moderately favourable motivation when monitoring co-occurred with supportive communication. By contrast, the performance-control profile displayed 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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