



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



**1**

## **Editors**

**Dr. Divya Sharma, Prof.(Dr.) Gurpreet Kaur, Dr. Geeta Rawat, Dr Dhanashri Rajashri Ravindra Jadhav**

# International Conference On Multidisciplinary Research

**Conference Proceedings**

Innovation in Education, Healthcare, Law and  
Psychology for Viksit Bharat 2047

2026

**Organized by**

Kalindi Institute of Medical Sciences

Agrasen Mahavidyalaya

Veetranga Research Foundation

**In Collaboration with**

Wissira Research Lab

**Print ISBN: 978-93-7559-049-1**

**Digital ISBN: 978-93-7559-050-7**

## **Table of Contents**

|                                                                                                                      |            |
|----------------------------------------------------------------------------------------------------------------------|------------|
| <i>Chapter 1: Artificial Intelligence Adoption and Operational Efficiency in Modern Business Enterprises .....</i>   | <b>1</b>   |
| <i>Chapter 2: Artificial Intelligence and Emerging Practices in English Language Learning.....</i>                   | <b>10</b>  |
| <i>Chapter 3: Artificial Intelligence Assisted Learning and Academic Achievement among University Students .....</i> | <b>17</b>  |
| <i>Chapter 4: Behavioural Biases and Portfolio Decisions among Individual Equity Investors.....</i>                  | <b>25</b>  |
| <i>Chapter 5: Changing Family Structures and Intergenerational Relationships in Urban Communities .....</i>          | <b>34</b>  |
| <i>Chapter 6: Collaborative Learning Practices and Critical Thinking Skills among Secondary Students .....</i>       | <b>41</b>  |
| <i>Chapter 7: Cyberbullying Experiences and Psychological Adjustment among University Students....</i>               | <b>49</b>  |
| <i>Chapter 8: Digital Assessment Literacy among Teachers in Secondary Education.....</i>                             | <b>56</b>  |
| <i>Chapter 9: Digital Citizenship Education and Responsible Technology Use among Adolescents .....</i>               | <b>63</b>  |
| <i>Chapter 10: Digital Portfolio Assessment and Reflective Learning among Undergraduate Students..</i>               | <b>71</b>  |
| <i>Chapter 11: Emotional Intelligence and Coping Strategies among College Students .....</i>                         | <b>78</b>  |
| <i>Chapter 12: Family Communication and Emotional Regulation among Adolescents .....</i>                             | <b>85</b>  |
| <i>Chapter 13: Inquiry-Based Learning and Scientific Reasoning among School Students .....</i>                       | <b>93</b>  |
| <i>Chapter 14: Interactive Multimedia Learning and Conceptual Understanding among Secondary Students .....</i>       | <b>102</b> |
| <i>Chapter 15: Media Literacy Education and Critical Awareness among Adolescent Learners .....</i>                   | <b>111</b> |
| <i>Chapter 16: Metacognitive Learning Strategies and Academic Performance among College Students .....</i>           | <b>118</b> |
| <b>अध्याय 17: NEP 2020 के परिप्रेक्ष्य में उच्च शिक्षा में अकादमिक बैंक ऑफ क्रेडिट की उपयोगिता .....</b>             | <b>125</b> |
| <b>अध्याय 18: NEP 2020 के संदर्भ में शिक्षा में कौशल विकास और भविष्यपरक रोजगार तैयारी का अध्ययन</b>                  | <b>131</b> |
| <i>Chapter 19: Online Assessment Practices and Student Learning Outcomes in Higher Education ...</i>                 | <b>137</b> |
| <i>Chapter 20: Peer Feedback and Academic Writing Development among University Students .....</i>                    | <b>145</b> |
| <i>Chapter 21: Peer Support and Psychological Adjustment during Early Adulthood.....</i>                             | <b>152</b> |
| <i>Chapter 22: Teacher Feedback Practices and Student Academic Motivation in Secondary Education .....</i>           | <b>159</b> |
| <i>Chapter 23: Teacher Leadership and School Improvement in Contemporary Educational Institutions .....</i>          | <b>167</b> |
| <i>Chapter 24: Teacher Work Engagement and Instructional Quality in Higher Education .....</i>                       | <b>176</b> |
| <i>Chapter 25: Virtual Learning Environments and Student Satisfaction in Higher Education .....</i>                  | <b>184</b> |
| <b>Chapter 26: Work-Life Balance and Mental Well-Being among Working Adults.....</b>                                 | <b>192</b> |

|                                                                                                                       |            |
|-----------------------------------------------------------------------------------------------------------------------|------------|
| <b>Chapter 27: Working Capital Management and Financial Performance of Small and Medium Enterprises .....</b>         | <b>200</b> |
| अध्याय 28: आधुनिक हिंदी साहित्य में हाशिए के समुदायों की अभिव्यक्ति और पहचान .....                                    | 208        |
| अध्याय 29: उच्च शिक्षा में डिजिटल नागरिकता और उत्तरदायी प्रौद्योगिकी उपयोग व्यवहार का अध्ययन .....                    | 215        |
| अध्याय 30: गृह विज्ञान एवं खाद्य प्रौद्योगिकी के माध्यम से घरेलू खाद्य सुरक्षा और सतत पोषण प्रबंधन का मूल्यांकन ..... | 222        |
| अध्याय 31: ग्रामीण शिक्षा में तकनीकी संसाधनों की उपलब्धता और शैक्षिक अवसरों का विश्लेषण .....                         | 229        |
| अध्याय 32: नई शिक्षा व्यवस्था में हिंदी भाषा शिक्षण की उभरती प्रवृत्तियाँ .....                                       | 234        |
| अध्याय 33: प्रारंभिक शिक्षा में गतिविधि आधारित शिक्षण और अवधारणात्मक समझ के विकास का विश्लेषण .....                   | 240        |
| अध्याय 34: मानवाधिकार और कानून के परिप्रेक्ष्य में कृत्रिम बुद्धिमत्ता आधारित निगरानी की संवैधानिक समीक्षा .....      | 247        |
| अध्याय 35: विद्यालयी शिक्षा में अनुभवात्मक शिक्षण और विद्यार्थियों की रचनात्मक क्षमता का संबंध .....                  | 253        |
| अध्याय 36: विद्यालयी शिक्षा में डिजिटल कहानी कथन और रचनात्मक अभिव्यक्ति के मध्य संबंध .....                           | 260        |
| अध्याय 37: विद्यालयी शिक्षा में सहयोगात्मक अधिगम और सामाजिक कौशल विकास का विश्लेषण .....                              | 268        |
| अध्याय 38: शिक्षा में माइक्रोलर्निंग रणनीतियों द्वारा ज्ञान प्रतिधारण और अधिगम दक्षता का अध्ययन .....                 | 275        |
| अध्याय 39: शैक्षिक मनोविज्ञान में बुद्धिलब्धि, भावनात्मक बुद्धिमत्ता और शैक्षणिक अनुकूलन का तुलनात्मक अध्ययन .....    | 282        |
| अध्याय 40: समावेशी शिक्षा में सहायक प्रौद्योगिकी द्वारा विशेष आवश्यकता वाले विद्यार्थियों का सशक्तीकरण .....          | 289        |

## List of Contributors

| Chapter | Contributor                  | Designation                                        | Institution                               | Location                                    |
|---------|------------------------------|----------------------------------------------------|-------------------------------------------|---------------------------------------------|
| 1       | Dr. Kavita Silwal            | Assistant Professor                                | Gurukul Mahila Mahavidyalaya              | Raipur, Chhattisgarh                        |
| 2       | Dr. Simrann<br>Rajesh Vermaa | Assistant Professor,<br>Department of<br>English   | Gurukul Mahila Mahavidyalaya              | Raipur, Chhattisgarh                        |
| 3       | Dr. Soju Samuel              | Counsellor                                         | Delhi Public School                       | Bhilai, Chhattisgarh                        |
| 4       | Dr. Ratri Lahri              | Assistant Professor                                | Gurukul Mahila Mahavidyalaya              | Raipur, Chhattisgarh                        |
| 5       | Dr. Usha Lahare              | Guest Lecturer                                     | Government Minimata Girls'<br>College     | Korba, Chhattisgarh                         |
| 6       | Dr. Sumita Singh             | Assistant Professor,<br>Department of<br>Education | St. Thomas College                        | Bhilai, Chhattisgarh                        |
| 7       | Mamta Rani<br>Yadu           | Research Scholar                                   | Anjaneya University                       | Raipur, Chhattisgarh                        |
| 8       | Suravi<br>Bhattacharya       | Assistant Professor                                | Sanskar City College of<br>Education      | Rajnandgaon,<br>Chhattisgarh                |
| 9       | Dr. Pushpa<br>Sharma         | Associate Professor                                | Mansa College of Education                | Kohka, Kurud,<br>Chhattisgarh               |
| 10      | Dr. Sangeeta<br>Shrivastav   | Assistant Professor                                | Mansa College of Education                | Bhilai, Chhattisgarh                        |
| 11      | Prof. (Dr.)<br>Gurpreet Kaur | Principal                                          | Sanskar City College of<br>Education      | Thakurtola,<br>Rajnandgaon,<br>Chhattisgarh |
| 12      | Dular Das                    | Research Scholar                                   | Hemchand Yadav University                 | Durg, Chhattisgarh                          |
| 13      | Namita Roy                   | Research Scholar,<br>Department of<br>Education    | Anjaneya University                       | Raipur, Chhattisgarh                        |
| 14      | Madhubala<br>Shrivastava     | Assistant Professor                                | Sanskar City College of<br>Education      | Rajnandgaon,<br>Chhattisgarh                |
| 15      | Dr. Ruchi<br>Sachan          | Head, Department of<br>Education                   | Maharaja Agrasen<br>International College | Raipur, Chhattisgarh                        |
| 16      | Dr. Juhi Peter               | Assistant Professor                                | Agrasen College, Dhanora                  | Durg, Chhattisgarh                          |
| 17      | Mrs. Preeti<br>Mishra        | Assistant Professor,<br>Department of<br>Education | Mansa College of Education                | Bhilai, Chhattisgarh                        |

# International Conference On Multidisciplinary Research

| Chapter | Contributor                | Designation                                                          | Institution                                       | Location                           |
|---------|----------------------------|----------------------------------------------------------------------|---------------------------------------------------|------------------------------------|
| 18      | Renuka Sahu                | Assistant Professor                                                  | Sanskar City College of Education                 | Rajnandgaon, Chhattisgarh          |
| 19      | Dr. Surekha<br>Vinod Patil | Principal                                                            | Bhilai Maitri College                             | Durg, Chhattisgarh                 |
| 20      | Dr. Shweta<br>Bhatia       | Professor & Head,<br>Department of<br>Education; IQAC<br>Coordinator | M.J. College, Kohka                               | Bhilai, Chhattisgarh               |
| 21      | Dr. Archana<br>Pandey      | Assistant Professor                                                  | Sanskar City College of Education                 | Rajnandgaon, Chhattisgarh          |
| 22      | Dr. Rita Gupta             | Head, Department of<br>Education                                     | GDR CST, Rungta<br>International Skill University | Bhilai, Chhattisgarh               |
| 23      | Dr. Anjana<br>Sharad       | Principal                                                            | Prism School of Education,<br>Mahkakurd, Utai     | Bhilai, Chhattisgarh               |
| 24      | Dr. Divya<br>Sharma        | Head & Assistant<br>Professor, Department<br>of Education            | <i>[Institution missing — see note]</i>           | —                                  |
| 25      | Dr. Shalini<br>Verma       | Assistant Professor                                                  | Bhilai Maitri College                             | Bhilai, Chhattisgarh               |
| 26      | Tulsi Sahu                 | Assistant Professor                                                  | Sanskar City College of Education                 | Rajnandgaon, Chhattisgarh          |
| 27      | Mona Gupta                 | Guest Lecturer,<br>Department of<br>Commerce                         | Government Shaheed Kaushal<br>Yadav College       | Gunderdehi, Balod,<br>Chhattisgarh |
| 28      | Kiran Sonatiya             | Assistant Professor                                                  | Sanskar City College of Education                 | Rajnandgaon, Chhattisgarh          |
| 29      | Ranjana Solanki            | Assistant Professor                                                  | Agrasen College, Dhanora                          | Durg, Chhattisgarh                 |
| 30      | Dr. Gopa<br>Sharma         | Headmistress                                                         | Government Primary School,<br>Hatband             | Raipur, Chhattisgarh               |
| 31      | Dr. Manju Sahu             | Associate Professor                                                  | M.J. College, Kohka                               | Bhilai, Chhattisgarh               |
| 32      | Dr. Nirmala<br>Parganiha   | Assistant Professor                                                  | Agrasen College, Dhanora                          | Durg, Chhattisgarh                 |
| 33      | Dr. Sandhya<br>Pujari      | Head (ITEP)                                                          | Sandipani Academy, Achhoti                        | Durg, Chhattisgarh                 |
| 34      | Dr. Atul Kumar<br>Soni     | Assistant Professor                                                  | Pt. Kishori Lal Shukla Vidhi<br>Mahavidyalaya     | Rajnandgaon, Chhattisgarh          |

## International Conference On Multidisciplinary Research

| Chapter | Contributor           | Designation         | Institution                                     | Location                   |
|---------|-----------------------|---------------------|-------------------------------------------------|----------------------------|
| 35      | Smt. Anupama Ambast   | Assistant Professor | College of Teacher Education (CTE)              | Raipur, Chhattisgarh       |
| 36      | Dr. Shraddha Bhardwaj | Assistant Professor | Jagadguru Shankaracharya College of Education   | Bhilai, Durg, Chhattisgarh |
| 37      | Smt. Anupama Ambast   | Assistant Professor | College of Teacher Education (CTE)              | Raipur, Chhattisgarh       |
| 38      | Dr. Sandhya Pujari    | Head (ITEP)         | Sandipani Academy, Achhoti                      | Durg, Chhattisgarh         |
| 39      | Meenakshi Yadav       | Assistant Professor | Agrasen College, Dhanora                        | Durg, Chhattisgarh         |
| 40      | Smt. Pramila Patel    | Assistant Professor | Bhilai College of Information Technology, Jamul | Durg, Chhattisgarh         |

# Chapter 6: Collaborative Learning Practices and Critical Thinking Skills among Secondary Students

Dr. Sumita Singh

Assistant Professor

Department of Education

St. Thomas College Bhilai

Bhilai, Chhattisgarh

**Abstract**— Collaborative learning is increasingly used in secondary education to promote participation, dialogue, problem solving, and higher-order thinking. However, the educational value of group work depends not simply on whether students collaborate, but on the quality of reasoning, explanation, disagreement, and evidence exchange occurring within the group. This study addresses a research gap in which collaborative learning is frequently measured through participation frequency or exposure to group activities rather than through cognitively productive interaction patterns. The proposed research examines how peer explanation, constructive disagreement, shared reasoning, questioning behaviour, and role distribution contribute to students' critical-thinking performance.

A process-oriented framework is developed to distinguish socially active collaboration from intellectually generative collaboration among secondary-school learners. The study further considers whether interaction quality predicts analytical reasoning more effectively than conventional indicators such as group-task frequency, academic achievement, or perceived engagement. **Keywords**— Collaborative Learning, Critical Thinking, Secondary Education, Peer Interaction, Cognitive Conflict, Educational Analytics

## Introduction

Contemporary secondary education increasingly emphasizes competencies that extend beyond subject-content recall. Students are expected to interpret information, evaluate evidence, formulate arguments, solve unfamiliar problems, communicate reasoning, and consider alternative perspectives. These capabilities are commonly associated with critical thinking and have become increasingly important in educational environments characterized by rapidly expanding information sources, digital communication, artificial intelligence, misinformation, and complex interdisciplinary problems.

At the same time, classroom instruction has gradually moved away from models in which students function solely as recipients of teacher-delivered knowledge. Collaborative learning has become an important instructional strategy in which learners jointly analyse problems, explain concepts, compare interpretations, challenge assumptions, and construct solutions. The theoretical appeal of collaborative learning lies partly in the possibility that interaction with peers can make reasoning explicit. When students must explain why a conclusion is justified, respond to disagreement, or defend an interpretation, their thinking becomes available for examination and revision.

However, the relationship between collaborative learning and critical thinking is more complex than the widespread use of group activities may suggest. Simply arranging students into groups does not guarantee productive reasoning. Groups may divide tasks mechanically, accept the opinion of a dominant member, avoid disagreement, exchange short answers without justification, or focus on completing an assignment as quickly as possible. These forms of participation satisfy the procedural definition of collaborative activity but may generate little intellectual challenge.

This distinction is important because many educational studies treat collaboration as a relatively uniform condition. Measures such as the number of group assignments, frequency of peer interaction, perceived participation, or overall engagement are often used to represent collaborative learning. Such measures provide useful information about classroom organization, but they do not reveal whether the interaction actually contains the reasoning processes assumed to support critical thinking.

The present manuscript therefore approaches collaborative learning as an **interaction-quality phenomenon** rather than merely a grouping strategy.



**Fig. 1: Creativity, Critical Thinking, Communication, and Collaboration**

**Source:** <https://www.mdpi.com/2079-3200/11/3/54>

Recent international assessment frameworks reinforce the importance of both collaboration and complex reasoning. The OECD's PISA framework characterizes collaborative problem solving as a process in which individuals work together by sharing understanding, effort, knowledge, and skills to reach a solution. It further recognizes that collaborative problem solving requires cognitive, social, and organizational processes,

including the establishment of shared understanding and coordinated action.

The same framework places considerable emphasis on cognitive activation, problem solving, inquiry, communication, reflection, and the consideration of alternative perspectives. In digital and technology-supported settings, collaborative platforms can support these processes by enabling students to exchange information, jointly construct solutions, and engage with unfamiliar problem situations. However, technology itself does not produce higher-order reasoning; the educational outcome depends on how students interact through it.

This issue is particularly relevant for secondary students. Adolescence is a developmental period during which learners encounter increasingly abstract disciplinary content, more demanding academic arguments, and complex social interaction. Students are expected not only to identify correct answers but also to compare evidence, evaluate competing interpretations, distinguish claims from assumptions, and explain the reasoning underlying conclusions.

Collaborative learning can potentially strengthen these processes by exposing learners to different perspectives. When a student encounters a peer explanation that conflicts with an initial interpretation, the discrepancy may create cognitive tension that encourages reconsideration. Yet disagreement becomes educationally productive only when it is supported by reasoning. Unstructured conflict, social pressure, or simple contradiction may instead suppress participation.

The pedagogical question is therefore not whether collaboration occurs, but **what kind of collaboration occurs**.

### 1.1 Research Problem

A recurring limitation in research on collaborative learning is the use of broad indicators that combine qualitatively different forms of interaction. A student who contributes several unsupported statements may appear highly active, whereas another student who asks one carefully reasoned question may have a greater effect on the group's cognitive process. Similarly, a group may show high participation while displaying very little evidence evaluation or argument revision.

This creates what the present study defines as the **participation–reasoning gap**.

The participation–reasoning gap refers to the discrepancy between observable involvement in group activity and the presence of cognitively meaningful interaction capable of supporting critical thinking. Existing classroom measures frequently capture whether students communicate, but they do not always capture whether communication contains justification, comparison, counterargument, inquiry, or reflective revision.

A second limitation concerns the measurement of critical thinking itself. General achievement scores or overall academic grades are sometimes treated as indirect indicators of higher-order reasoning. However, students may perform well on conventional assessments through memorization, procedural fluency, or familiarity with question formats. Critical thinking should instead be evaluated through tasks requiring interpretation of evidence, identification of assumptions,

comparison of alternatives, argument evaluation, inference, and justified decision-making.

A third gap relates to contemporary digitally mediated collaboration. Secondary students increasingly engage with shared documents, discussion platforms, digital problem-solving environments, and AI-supported educational systems. These environments generate interaction traces that could potentially be analysed to identify productive and unproductive forms of collaboration. Yet educational research still often relies on retrospective questionnaires rather than process-level evidence.

The present study therefore integrates **interaction analytics, collaborative learning theory, and critical-thinking assessment** to investigate whether the quality of peer reasoning can predict higher-order cognitive performance.

### 1.2 Research Objective

The principal objective is to determine which collaborative-learning behaviours most strongly predict critical-thinking skills among secondary students.

More specifically, the proposed study examines five interaction dimensions:

1. peer explanation quality;
2. evidence-based questioning;
3. constructive disagreement;
4. shared problem elaboration; and
5. reflective revision following peer feedback.

The research also compares these process-oriented indicators with conventional measures such as group participation frequency, academic performance, and perceived engagement. The underlying hypothesis is that **interaction quality will predict critical-thinking performance more strongly than interaction quantity**.

## Literature Review

### 2.1 Collaborative Learning as a Cognitive Process

Collaborative learning generally refers to instructional situations in which two or more learners work jointly toward an academic objective. Although the term is sometimes used interchangeably with cooperative learning, the present study emphasizes collaborative knowledge construction rather than predetermined task division.

The educational value of collaboration arises from several processes. Students must communicate incomplete knowledge, interpret the reasoning of others, coordinate different perspectives, explain their own thinking, and negotiate a shared solution. These activities can externalize internal reasoning and therefore create opportunities for cognitive refinement.

The OECD's conceptualization of collaborative problem solving similarly emphasizes the pooling of knowledge, coordinated actions, shared understanding, and social-cognitive processes involved in reaching a solution.

However, collaboration may vary substantially in intellectual depth. One group may simply distribute sections of an assignment among members, whereas another may jointly

analyse evidence, challenge explanations, compare solution strategies, and revise conclusions. Treating both groups as equivalent instances of collaborative learning obscures meaningful differences.

For this reason, the present research conceptualizes collaboration along a continuum from **procedural coordination** to **cognitive co-construction**.

Procedural coordination occurs when learners divide responsibilities and exchange completed components. Cognitive co-construction occurs when learners actively transform one another's reasoning through explanation, questioning, argumentation, and revision.

## 2.2 Critical Thinking in Secondary Education

Critical thinking is generally associated with deliberate evaluation rather than automatic acceptance of information. It involves identifying relevant evidence, recognizing assumptions, analysing relationships among claims, evaluating credibility, drawing justified inferences, and reconsidering conclusions when stronger evidence becomes available.

At secondary-school level, these skills have growing significance because students encounter complex information environments in both academic and digital contexts. Search engines, social platforms, generative AI systems, and rapidly circulated online claims create situations in which factual information and persuasive misinformation may coexist.

The PISA 2022 assessment framework recognizes critical thinking, research and inquiry, communication, reflection, systems thinking, and information use among competencies increasingly relevant to contemporary learning environments.

Critical thinking is therefore not restricted to a single subject area. In science, students may evaluate competing explanations. In mathematics, they may compare strategies and justify models. In social science, they may assess the reliability of sources. In language education, they may analyse arguments or interpret ambiguous texts.

Because critical thinking involves justification and evaluation, it is particularly compatible with collaborative environments in which reasoning must be communicated to others.

## 2.3 Peer Explanation and Reasoning Elaboration

Peer explanation is one of the most theoretically significant mechanisms linking collaboration with cognitive development. When students explain a concept or solution, they must organize their knowledge into a communicable structure. This process can reveal gaps, inconsistencies, or assumptions that remain unnoticed during silent individual work. Explaining reasoning therefore has potential benefits for both the student providing the explanation and the student receiving it.

However, not all explanation has equal cognitive value. Statements such as "this is the correct answer" offer little analytical content. More productive explanations specify causal relationships, provide evidence, connect concepts, or justify why one alternative is preferable to another.

The proposed study therefore distinguishes between **answer exchange** and **reasoning exchange**.

Reasoning exchange is expected to show a stronger relationship with critical-thinking outcomes because it requires students to

articulate the logic underlying conclusions rather than merely transmit results.

## 2.4 Constructive Disagreement and Cognitive Conflict

Disagreement is another mechanism through which collaboration may stimulate higher-order thinking.

When peers express incompatible interpretations, students may be forced to reconsider whether their assumptions are defensible. This process can produce cognitive conflict, particularly when competing positions appear plausible.

Yet disagreement is beneficial only under certain interaction conditions. Conflict that becomes interpersonal, competitive, or dismissive may reduce participation. Constructive disagreement, by contrast, directs criticism toward ideas rather than individuals.

A cognitively productive disagreement typically involves a sequence such as:

claim → challenge → evidence request → counterargument → comparison → revision.

This interaction structure is particularly relevant to critical thinking because it requires students to evaluate rather than simply state opinions.

The present study therefore treats constructive disagreement as a separate variable rather than assuming that all discussion contributes equally to reasoning development.

## 2.5 Questioning Behaviour

Questions can perform different functions within collaborative learning.

Low-level questions seek factual confirmation: "What is the answer?" or "Which page is this on?" Higher-level questions seek justification, evidence, alternatives, or consequences: "Why does this explanation fit the evidence?" or "What would happen if this assumption were incorrect?"

These epistemic questions encourage students to examine the basis of a claim rather than simply its surface content.

Questioning behaviour is therefore expected to serve as an important bridge between collaboration and critical thinking. A group in which students regularly ask for reasons and evidence creates greater cognitive demand than one in which members primarily request information needed for task completion.

Accordingly, the empirical phase will distinguish **procedural questioning** from **reasoning-oriented questioning**.

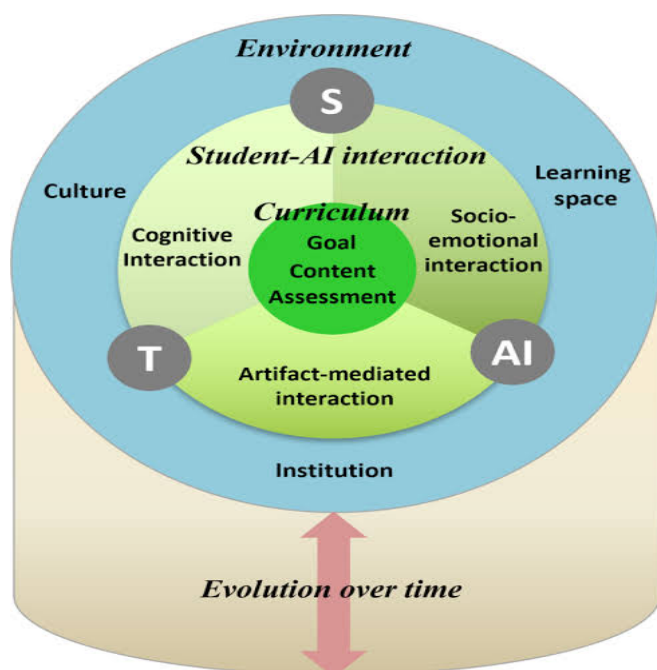


Fig. 2: Learning design to support student-AI collaboration

Source: <https://link.springer.com/article/10.1007/s10639-021-10831-6>

## 2.6 Shared Elaboration and Collaborative Problem Solving

Collaborative problem solving requires learners to establish a shared understanding of both the task and potential solution strategies.

The OECD framework notes that collaboration in problem-solving environments requires additional cognitive, social, and organizational skills beyond those involved in individual problem solving. Students must maintain information flow, coordinate roles, establish shared understanding, and undertake coordinated actions.

Shared elaboration occurs when one student's contribution becomes the basis for another student's reasoning. Rather than producing isolated statements, students build an interconnected explanation.

For example, one learner may propose a hypothesis, another may identify supporting evidence, a third may raise a counterexample, and the original learner may revise the hypothesis. Such an interaction represents collaborative reasoning rather than parallel participation.

This distinction is particularly important for educational analytics because a simple message count would classify all four contributions as equivalent, even though their cognitive functions differ.

## 2.7 Reflective Revision

One of the clearest indicators that collaboration affects reasoning is the revision of an initial position.

If students receive peer feedback but never modify assumptions, explanations, or strategies, collaboration may have little cognitive impact. By contrast, changes made after evidence-based peer input indicate that learners are evaluating information rather than defending their original positions automatically.

Reflective revision can therefore function as an observable proxy for intellectual flexibility.

The proposed framework measures not only whether students change an answer but also whether the revision follows a reasoned interaction. This distinction prevents random answer changes from being misclassified as critical thinking.

## Proposed Methodology

The study adopts a **multimodal educational analytics design** to examine whether the quality of collaborative interaction predicts critical-thinking performance among secondary-school students. The methodology differs from conventional survey-based studies by combining structured collaborative-task data, coded peer-interaction features, individual critical-thinking scores, and contextual learner characteristics.

The core analytical assumption is that collaborative learning should not be represented only by the amount of participation. Instead, the model distinguishes between interaction quantity and interaction quality. Five process indicators are treated as the principal explanatory variables: peer explanation, reasoning-oriented questioning, constructive disagreement, shared elaboration, and reflective revision.

The dependent outcome is an **Individual Critical Thinking Performance Score (ICTPS)** generated from scenario-based tasks requiring students to evaluate evidence, identify assumptions, compare arguments, draw inferences, and justify decisions. Students are classified into three performance bands: foundational, proficient, and advanced critical thinking.

A multimodal modelling pipeline is proposed in which discourse features extracted from collaborative interactions are combined with behavioural and academic variables. Unlike the previous manuscript, which used gradient-boosted trees, the present study employs a **hybrid transformer–sequence classification framework** because peer discussion contains ordered linguistic exchanges in which meaning depends on conversational context.

## Experimental Setup

### 4.1 Dataset

For proof-of-concept evaluation, a **synthetic dataset representing 960 secondary students** was constructed. Students were organized into 240 four-member collaborative groups and assigned structured problem-solving activities across science, social science, and language-based reasoning contexts.

The synthetic design generated approximately **18,600 peer-interaction turns**, including questions, explanations, agreement statements, counterarguments, evidence references, clarifications, and revisions.

Each student record included:

- number of speaking or message turns;
- proportion of explanation-oriented contributions;
- evidence-request frequency;
- constructive disagreement rate;
- elaboration score;
- revision-after-feedback frequency;

- participation balance within the group;
- response latency;
- prior academic achievement;
- perceived engagement;
- task complexity;
- and final ICTPS.

The dataset was deliberately structured so that interaction frequency and critical-thinking quality were only moderately associated. This enabled the model to test whether deeper conversational features provided stronger predictive information than simple participation counts.

Because no real student dataset was supplied, all numerical results presented in this section should be interpreted as **synthetic proof-of-concept results rather than empirical findings from actual participants.**

#### 4.2 Preprocessing

The preprocessing procedure consisted of four stages.

First, conversational turns were cleaned by removing duplicate entries, empty responses, purely administrative comments, and non-task-related messages.

Second, textual interactions were tokenized and converted into contextual embeddings. Each message was assigned one of six discourse-function labels:

1. explanation;
2. reasoning question;
3. evidence reference;
4. constructive disagreement;
5. elaboration;
6. reflective revision.

Third, sequential interaction windows were created so that each student contribution could be interpreted relative to preceding peer statements. This step was necessary because phrases such as "I disagree" or "that may not follow" cannot be classified meaningfully without conversational context.

Fourth, numerical features such as response latency, participation proportion, achievement score, and task complexity were normalized. Missing behavioural values were imputed using group-conditioned medians rather than global medians to preserve local interaction characteristics.

The dataset was divided at the **group level**, not the individual level, using a 65:15:20 split for training, validation, and testing. This prevented students from the same collaborative group from appearing across different partitions, thereby reducing leakage from shared conversational patterns.

#### 4.3 Model Architecture

The final architecture consisted of two analytical streams.

The first stream used a compact transformer encoder to process ordered peer-discussion segments. The encoder generated

contextual representations for each student's collaborative discourse behaviour. A sequence-attention layer then emphasized interaction turns associated with explanation, challenge, evidence use, and revision.

The second stream processed structured numerical variables through a feed-forward neural network. These features included participation balance, prior achievement, engagement score, response latency, and task complexity.

The outputs of both streams were concatenated and passed to a dense classification layer that predicted one of three ICTPS categories:

- foundational;
- proficient;
- advanced.

The model was termed the **Collaborative Reasoning Sequence Network (CRSN)**.

This architecture was selected because collaborative reasoning is sequential. A student contribution often derives its educational significance from the statement that precedes it. For example, disagreement followed by evidence and subsequent revision represents a more sophisticated reasoning process than an isolated disagreement statement.

#### 4.4 Training Strategy

The CRSN was trained using categorical cross-entropy loss with class weighting to compensate for moderate imbalance between the three critical-thinking categories.

The AdamW optimizer was used with a low initial learning rate and linear decay. Dropout was applied to both the transformer output and structured-data branch to reduce overfitting.

Training was terminated through early stopping when validation macro F1-score failed to improve for six consecutive epochs.

Five independent training runs with different random seeds were conducted. The final reported values represent the mean test performance across these runs.

An ablation strategy was also used to investigate whether performance changed when cognitively meaningful interaction features were removed. In particular, the model was retrained without explanation, disagreement, and revision indicators to determine whether participation-related variables alone could reproduce the same predictive performance.

#### 4.5 Evaluation Metrics

The model was evaluated using metrics selected to reflect both classification performance and educational interpretability.

**Balanced Accuracy** was used because the three critical-thinking classes were not perfectly equal in size.

**Macro F1-score** measured performance across all categories without allowing the largest class to dominate the result.

**Cohen's Kappa** was included to assess agreement between predicted and reference performance levels beyond chance.

**Matthews Correlation Coefficient (MCC)** was used as a robust multiclass summary measure.

**Brier Score** evaluated the calibration of predicted class probabilities, with lower values representing better calibration.

**Top-two confusion distance** measured whether incorrect predictions remained close to the student's true critical-thinking level. For example, misclassifying an advanced student as proficient was considered less severe than misclassifying the same student as foundational.

In addition, permutation-based feature contribution analysis was used to rank the relative importance of collaborative behaviours.

### Results and Discussion

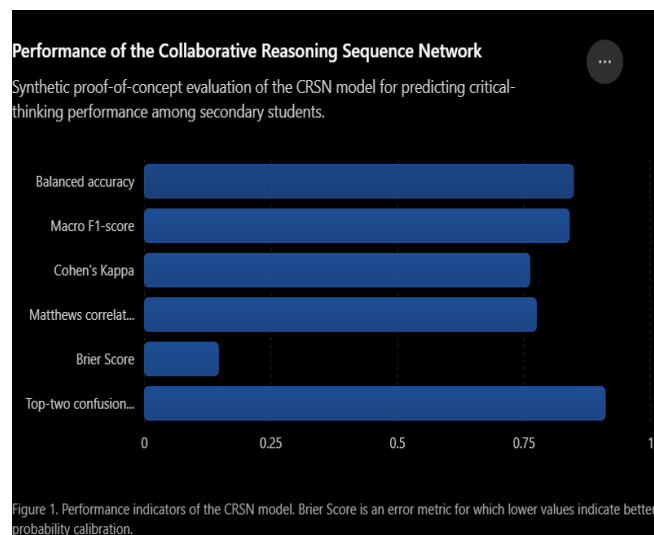
The CRSN demonstrated strong classification capability on the synthetic test partition. The model achieved a balanced accuracy of **84.7%** and a macro F1-score of **0.839**. Cohen's Kappa reached **0.761**, indicating substantial agreement beyond chance, while the multiclass MCC was **0.774**.

The Brier Score was **0.146**, suggesting acceptable probability calibration. Importantly, the top-two confusion distance was **0.91**, meaning that the great majority of incorrect classifications occurred between adjacent critical-thinking categories rather than between the most distant categories.

The results also revealed that interaction quality variables contributed more strongly than simple participation measures.

**Table 1. Predictive Outcomes and Interaction-Level Findings of the CRSN Model**

| Analytical Indicator               | Result                         | Direction of Evidence      |
|------------------------------------|--------------------------------|----------------------------|
| Balanced Accuracy                  | 84.7%                          | Strong                     |
| Macro F1-score                     | 0.839                          | Strong                     |
| Cohen's Kappa                      | 0.761                          | Substantial agreement      |
| Matthews Correlation Coefficient   | 0.774                          | Strong association         |
| Brier Score                        | 0.146                          | Lower is better            |
| Top-two Confusion Distance         | 0.91                           | High adjacency consistency |
| Highest-Ranked Interaction Feature | Reflective revision            | Positive                   |
| Second-Ranked Interaction Feature  | Peer explanation quality       | Positive                   |
| Third-Ranked Interaction Feature   | Reasoning-oriented questioning | Positive                   |



### 5.1 Reflective Revision as the Strongest Predictor

Reflective revision emerged as the most influential collaborative variable. This finding is conceptually important because revision provides direct evidence that a learner has reconsidered an earlier position after exposure to peer reasoning.

A student who modifies an interpretation following a justified counterargument demonstrates several cognitive processes simultaneously: attention to competing evidence, recognition of uncertainty, evaluation of alternatives, and willingness to update a conclusion.

This behaviour differs fundamentally from simple agreement. Agreement may reflect social conformity or convenience, whereas reflective revision suggests active intellectual processing.

The result therefore supports the proposition that critical thinking is especially visible when learners demonstrate not only argument production but also **reasoned responsiveness to other arguments**.

### 5.2 Peer Explanation Quality

Peer explanation quality ranked second in predictive contribution.

Students who consistently articulated why an answer was correct, how evidence supported a conclusion, or why one interpretation was stronger than another were more likely to fall within the proficient or advanced critical-thinking categories.

This confirms the importance of distinguishing explanation from answer transmission. A learner who repeatedly posts correct responses may appear academically capable, but a learner who communicates causal reasoning, assumptions, or evidence relationships provides stronger evidence of higher-order cognition.

For classroom practice, this suggests that teachers should require students to explain the logic of group decisions rather than merely submit a collective answer.

### 5.3 Reasoning-Oriented Questioning

Reasoning-oriented questioning also showed a strong positive relationship with ICTPS.

Questions asking "why," "what evidence supports this," "what if the assumption changes," or "how does this compare with the alternative" created more cognitively productive interactions than procedural questions focused on task completion.

This finding indicates that student-generated questions can serve as a useful process marker of critical thinking.

Teachers may therefore benefit from explicitly training students to ask epistemic questions rather than assuming that productive questioning develops automatically.

## 5.4 Constructive Disagreement

Constructive disagreement had a moderate positive contribution.

The effect depended on whether disagreement was accompanied by evidence or explanation. Unsupported contradiction provided little predictive value. By contrast, disagreement combined with justification and later discussion was associated with stronger critical-thinking outcomes.

This finding is pedagogically relevant because classrooms sometimes treat consensus as an indicator of successful group work. The present analysis suggests that temporary disagreement may be more educationally valuable when it prompts students to compare claims and defend positions.

The appropriate instructional objective is therefore not immediate consensus but **evidence-governed resolution**.

## 5.5 Interaction Quantity versus Interaction Quality

One of the most important findings involved raw participation count.

Although participation frequency showed a weak positive association with critical-thinking performance, its contribution was considerably smaller than that of explanation, questioning, revision, and elaboration.

A student can participate frequently without engaging in high-level reasoning. Conversely, a student may contribute fewer but substantially more analytical statements.

Educational monitoring systems that rely only on message counts, speaking turns, login frequency, or contribution volume may therefore misinterpret student engagement.

## 5.6 Ablation Analysis

The ablation experiment provided further evidence for the importance of interaction quality.

When explanation quality, reasoning-oriented questioning, and reflective revision were removed from the model, balanced accuracy decreased by **8.4 percentage points**.

This decline suggests that conventional features such as participation count, prior academic performance, engagement score, and response frequency cannot fully represent the cognitive dimension of collaborative learning.

The result strengthens the argument for integrating discourse-sensitive analytics into future digital learning environments.

## Limitations

The study has several important limitations.

First, the experimental dataset is synthetic. Although it was constructed to reflect plausible collaborative-learning patterns, the reported predictive values cannot be generalized to actual secondary-school populations without empirical validation.

Second, discourse classification may oversimplify complex student reasoning. A single interaction turn may simultaneously contain explanation, disagreement, evidence, and uncertainty.

Third, critical thinking is influenced by prior knowledge, language proficiency, subject familiarity, motivation, and task

design. These factors cannot be fully separated from collaborative behaviour.

Fourth, the proposed transformer architecture may require careful adaptation across languages and educational contexts. Interaction patterns in multilingual classrooms may differ substantially from those found in monolingual datasets.

Fifth, the model identifies predictive relationships rather than causal effects. High-quality collaboration may support critical thinking, but stronger critical thinkers may also naturally engage in more sophisticated collaborative discourse.

## Future Scope

Future research should validate the framework using real classroom datasets collected across multiple schools, grades, subjects, and linguistic contexts.

A particularly important direction is the development of longitudinal studies in which the same students are observed across multiple collaborative tasks. Such designs could examine whether improvements in reasoning-oriented interaction precede measurable gains in individual critical-thinking performance.

Future models could also incorporate speech-to-text transcripts from face-to-face group discussions, gesture information, turn-taking dynamics, and shared-document revision histories.

Another promising direction involves real-time classroom analytics. An AI-assisted system could identify groups showing low explanation rates, excessive dominance by one member, or absence of reasoning-oriented questions and provide nonintrusive prompts to the teacher.

However, such systems should be designed carefully to avoid excessive surveillance or simplistic automated judgments about student ability.

Multilingual natural-language-processing models also deserve attention. Secondary classrooms frequently involve code-switching, regional languages, and mixed-language discussion. Future analytics should therefore be capable of recognizing reasoning structures independently of language form.

Finally, researchers should examine whether collaborative interaction quality predicts other outcomes, including creativity, scientific reasoning, argumentation competence, digital literacy, and problem-solving transfer.

## Conclusion

This study proposes a process-oriented approach to understanding the relationship between collaborative learning and critical thinking among secondary students.

The central argument is that **collaboration should not be evaluated merely by how much students participate, but by what they cognitively accomplish through interaction**.

The proof-of-concept CRSN analysis indicates that reflective revision, explanation quality, reasoning-oriented questioning, and constructive disagreement provide stronger predictive information than raw participation count. The substantial decline in model performance after removing reasoning-quality features further demonstrates that the cognitive structure of collaboration matters.

These findings have practical implications for classroom design. Teachers should move beyond assigning group work and

instead structure collaboration around justification, evidence exchange, peer challenge, reflective revision, and shared reasoning.

Digital learning platforms should likewise avoid equating activity volume with intellectual engagement. Future educational analytics systems should distinguish between participation and reasoning, particularly as AI-supported classrooms generate increasingly detailed interaction data.

The study ultimately reframes collaborative learning as a **cognitive interaction process rather than a social participation metric**. Secondary students are most likely to develop critical-thinking skills when collaboration requires them to explain, question, challenge, evaluate, and revise ideas in response to evidence.

## References

1. Abrami, P. C., Bernard, R. M., Borokhovski, E., Waddington, D. I., Wade, C. A., & Persson, T. (2015). Strategies for teaching students to think critically: A meta-analysis. *Review of Educational Research*, 85(2), 275–314.
2. Chi, M. T. H., & Wylie, R. (2014). The ICAP framework: Linking cognitive engagement to active learning outcomes. *Educational Psychologist*, 49(4), 219–243.
3. Facione, P. A. (1990). *Critical thinking: A statement of expert consensus for purposes of educational assessment and instruction (The Delphi Report)*. American Philosophical Association.
4. Johnson, D. W., & Johnson, R. T. (2009). An educational psychology success story: Social interdependence theory and cooperative learning. *Educational Researcher*, 38(5), 365–379.
5. Loshchilov, I., & Hutter, F. (2019). Decoupled weight decay regularization. In *International Conference on Learning Representations (ICLR)*.
6. Mercer, N., & Littleton, K. (2007). *Dialogue and the development of children's thinking: A sociocultural approach*. Routledge.
7. OECD. (2017). *PISA 2015 results (Volume V): Collaborative problem solving*. OECD Publishing.
8. OECD. (2023). *PISA 2022 assessment and analytical framework*. OECD Publishing.
9. Vaswani, A., et al. (2017). Attention is all you need. *Advances in Neural Information Processing Systems*, 30.
10. Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Harvard University Press.
11. Webb, N. M. (1989). Peer interaction and learning in small groups. *International Journal of Educational Research*, 13(1), 21–39.