Perceptions of Science Trainee Teachers on Collaborative Learning towards Critical Thinking Skills: A Conceptual Paper

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ABSTRACT

Twenty first century science education prioritises student centred pedagogies that cultivate collaboration and critical thinking. Anchored in Vygotsky's sociocultural theory (1978), particularly the zone of proximal development and the mediating role of language and tools, this conceptual paper proposes a framework for how collaborative learning nurtures critical thinking cognitive skills together with dispositions such as open mindedness, intellectual humility, and truth seeking among preservice science teachers. The framework rests on positive interdependence, promotive interaction, individual accountability, and structured reflection, and it advances three pathways. First, dialogic exchange within the zone of proximal development surfaces and resolves misconceptions and strengthens reasoning. Second, task interdependence elicits metacognitive monitoring and justification through scaffolded assistance. Third, role rotation and peer feedback normalise evidence seeking dispositions and support the internalisation of regulatory talk. Gender is treated as a contextual lens that shapes participation and discourse, and equitable roles and argumentation protocols are proposed to mitigate imbalance. From this framework follow design principles for initial teacher education, including the use of authentic and ill structured problems, explicit scripting of discourse moves such as claim, evidence, and reasoning, rubric guided assessment of skills and dispositions, and sequenced activities that consolidate gains over time. The paper concludes with a research agenda to test the framework using validated measures and equity sensitive designs.

Keywords: Collaborative Learning, Critical Thinking Cognitive Skills, Critical Thinking Dispositions, Science Education

INTRODUCTION

In the 21st century, education has shifted from traditional methods focused on rote memorisation to student-centred approaches that promote critical thinking, communication and collaboration skills (Fadhilawati et al., 2023). Collaborative learning, a powerful strategy for enhancing knowledge acquisition and higher-order thinking, encourages students to engage actively with peers, exchange ideas and refine their understanding (Kavita, 2024). Also, research has shown that collaborative learning increases students' attitudes and motivation towards science learning, while also enhances their ability to transfer knowledge and generate new ideas in real-world problems (Loes & Pascarella, 2017). Thus, collaborative learning could help in fostering critical thinking skills, providing a structured way for students to explore complex concepts and apply scientific reasoning in collaborative settings.

Critical thinking, an essential skill for science education, is crucial for understanding scientific concepts and solving complex problems. Studies indicate that students with strong critical thinking skills perform better academically and are more adapted at solving complex scientific problems (Ramdani et al., 2022). Critical thinking skills involve critical thinking cognitive skill, the mental processes required for effective reasoning, problem-solving and decision-making. These skills include interpretative analysis, inference, evaluation, explanation and self-regulation which help to process information systematically, make sound judgements and improve reasoning abilities. (Echiverri, 2024; Fikriyati et al., 2022). On the other hand, critical thinking dispositions are another part of critical thinking which refer to the attitudes, habits of mind and personal traits that support effective critical thinking, ensuring a balanced and well-reasoned judgement (Santos, 2017). These include confidence, open mindset, fairness and objectivity, scepticism and systematically (Echiverri, 2024; Fikriyati et al., 2022).

Research indicates that collaborative learning promotes critical thinking by encouraging students to question assumptions, articulate thoughts and consider diverse perspectives (Hsu, 2021). Thus, research indicates that students who engage in collaborative learning activities like group discussions and peer teaching enhance analytical and reasoning skills, thereby improving academic performance and problem-solving abilities (Isnawati et al., 2020).

An important dimension of critical thinking skills development in collaborative contexts is gender. Research has shown that gender can influence learning preferences, communication styles, and participation patterns in group-based settings (Gilligan, 1982; Chai et al., 2021). In science education, studies report mixed findings: some indicate that female pre-service teachers exhibit stronger verbal reasoning and reflection in collaborative learning, while male counterparts may demonstrate greater confidence in problem-solving tasks (Tan & Karim, 2021). These differences highlight the need to examine whether perceptions of collaborative learning as a pathway to critical thinking skills development vary by gender.

A. Research Objectives

1. To determine the perceived contribution of collaborative learning to critical-thinking cognitive skills and dispositions among preservice science teachers
2. To determine whether mean perceived contributions differ by gender.
3. To determine whether critical thinking dispositions mediate the relationship between collaborative learning and reasoning quality.
4. To model which collaborative features predict critical thinking skills and dispositions after controlling for relevant covariates.

B. Research Questions

1. What are the mean levels of the perceived contribution of collaborative learning to critical thinking cognitive skills and to critical thinking dispositions?
2. Do these mean perceived contributions differ by gender?
3. Do critical thinking dispositions mediate the relationship between collaborative learning and reasoning quality?
4. Which collaborative features predict critical thinking skills and dispositions, controlling for relevant covariates?

LITERATURE REVIEW

Collaborative learning can enhance engagement and higher order outcomes, but effects depend on task design, discourse scripting and individual accountability (Johnson & Johnson, 1991; Kirschner, Oliver, M., et al. 2023). In science education, peer interaction, social presence and authentic inquiry can support achievement, yet benefits are contingent on assessment quality and facilitation rather than universal (Garrison, Anderson, & Archer, 2000; Qureshi, Khaskheli, Qureshi, Raza, & Yousufi, 2023). Strong guidance and scaffolding matter, because minimal guidance risks cognitive overload and uneven participation in novice groups (Kirschner et al., 2006). These patterns align with sociocultural views that emphasise guided interaction, while reminding us that social presence is a prerequisite but not a guarantee of rigorous inquiry (Vygotsky, 1978; Garrison et al., 2000).

Empirically, the link between collaborative learning and critical thinking is generally positive but modest, and is sensitive to dosage, structure and context (Loes & Pascarella, 2017). Dispositions such as openness and confidence improve under structured peer feedback, but gains are typically smaller than for cognitive skills, which signals the need for explicit discourse norms and formative rubrics (Loes & Pascarella, 2017). For pre service teachers, capacity building requires more than exposure; targeted professional development and clear collaboration scripts produce stronger and more durable effects (Qureshi et al., 2023; Vygotsky, 1978).

On gender, differences are usually small and design dependent; responsive scaffolding and equitable turn taking tend to narrow gaps rather than magnify them (Loes & Pascarella, 2017; Vygotsky, 1978). Future studies should report intervention dose, specify collaboration scripts and accountability mechanisms, and use multi measure outcomes with moderators such as duration, social presence, and gender to identify when and why collaborative learning improves critical thinking in science (Garrison et al., 2000; Loes & Pascarella, 2017).

Conceptual Framework

The conceptual framework of this study illustrates the interrelationship between collaborative learning, interaction, critical thinking skills and dispositions, and the quality of science learning among pre-service teachers. This model is grounded in Vygotsky's Social Constructivism Theory (1978), which posits that learning occurs through social interaction and the co-construction of knowledge. Within collaborative settings, learners are exposed to diverse ideas that promote negotiation of meaning and the development of higher-order thinking processes (Saleem et al., 2021; Wibowo et al., 2025). Applied examples show that virtual lab and simulation contexts create interactive, collaborative spaces in which meaning is negotiated and higher order reasoning is practised; similarly, Scratch based tasks can surface misconceptions and guide conceptual change through peer discussion **(**Lee & Chongo, 2025; Lim & Chongo, 2025; Chia et al., 2023; Ming et al., 2023). Thus, collaborative learning is positioned as the pedagogical arena in which social interaction is organized and meaning is negotiated, providing a clear bridge to the subsequent account of dialogue, cooperation, and shared problem solving.

Collaborative learning provides a pedagogical platform that engages learners in dialogue, cooperation, and shared problem-solving, creating an environment conducive to joint intellectual effort (Johnson & Johnson, 1991; Bruffee, 1995). Through cooperative structures, students assume responsibility not only for their own learning but also for the collective understanding of the group. This shared accountability encourages positive interdependence and individual accountability, two conditions shown to enhance academic achievement and reasoning (Laal & Ghodsi, 2012).

Interaction acts as the mediating process that connects collaborative learning with the development of critical thinking. In interactive discourse, learners articulate arguments, justify claims, and respond to counter-perspectives, practices that refine cognitive reasoning and foster reflective judgment (Hsu, 2021)). Interactional quality, rather than frequency alone, determines how effectively collaborative activities stimulate deeper levels of reasoning. Research demonstrates that dialogic interaction nurtures analytical skills, hypothesis testing, and the ability to evaluate evidence critically (Loes & Pascarella, 2017; Qureshi et al., 2023).

Through these interactions, critical thinking cognitive skills such as interpretation, analysis, inference, evaluation, explanation, and self-regulation are activated and refined (Echiverri, 2024; Fikriyati et al., 2022). Simultaneously, critical thinking dispositions, including open-mindedness, confidence, intellectual curiosity, and fairness, are cultivated through sustained collaboration and constructive feedback (Ekici, 2017; Hamzah et al., 2024).Students engaged in well-structured collaborative learning tasks tend to demonstrate higher perseverance, empathy, and willingness to reassess assumptions, aligning with the traits of strong critical thinkers (Santos, 2017).

When both cognitive and dispositional dimensions of critical thinking are developed, learners exhibit a deeper comprehension of scientific concepts and enhanced capacity for evidence-based reasoning. This leads to measurable improvements in the quality of science learning, characterized by conceptual understanding, metacognitive awareness, and the ability to transfer scientific reasoning to real-world contexts (García-Carmona, 2023; Muhibbuddin et al., 2023). Furthermore, the integration of collaborative inquiry with reflective dialogue promotes sustained intellectual engagement and professional growth among pre-service science teachers (Mandikonza, 2022).

As depicted in Fig. 1, the proposed framework conceptualizes the pathway.

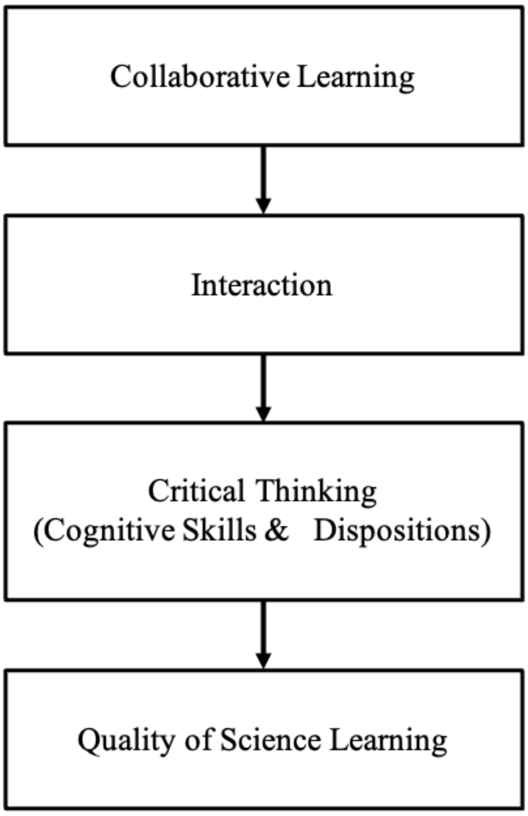

Fig. 1 Conceptual framework

This framework underscores that collaborative learning indirectly enhances the quality of science education by mediating social interaction processes that strengthen both the cognitive and affective domains of critical thinking. Future empirical studies could validate this framework through structural modeling to confirm the mediating influence of interaction on science learning outcomes. This conceptual paper proposes to explore the perceptions of science trainee teachers towards collaborative learning in developing critical thinking skills, with a specific focus on the potential differences in perceptions based on gender. Understanding these perceptions will provide insights into how teacher education programs can design more inclusive and effective collaborative learning experiences to nurture critical thinking skills competencies across diverse learner profiles.

METHODOLOGY

A. Research Design

This article adopts a conceptual model building design rather than an empirical survey, while articulating a quantitative pathway for future testing. Our aim is to theorise how specific collaborative task features, structured discourse, individual accountability, and feedback cycles shape two outcomes in science education, namely critical thinking cognitive skills and critical thinking dispositions. We integrate sociocultural accounts of guided participation and the Community of Inquiry tradition to explain the mechanisms that move interaction from social presence to disciplined reasoning, and we specify testable propositions and scope conditions under which effects should strengthen or attenuate (Garrison, Anderson, & Archer, 2000; Vygotsky, 1978). In doing so, we follow guidance for high quality conceptual contributions. We emphasise construct clarity, internal coherence, parsimony balanced with explanatory fertility, and practical usefulness for future empirical testing (MacInnis, 2011; Jaakkola, 2020). We also reconcile supportive and cautionary evidence by arguing that collaborative learning yields stronger gains when explicit scaffolding is present, while minimally guided approaches risk overload and uneven participation in novice groups (Kirschner, Sweller, & Clark, 2006; Hmelo Silver, Duncan, & Chinn, 2007). A brief prospective testing plan is outlined to show how the model could be operationalised in subsequent studies without eclipsing its primary theoretical contribution.

B. Sampling

Sampling is outlined to show how the proposed model can be subjected to empirical testing without eclipsing its theoretical contribution. Accordingly, we define the target population, articulate the sampling logic, and specify reporting principles that enable rigorous tests while preserving the paper's conceptual focus (Jaakkola, 2020; MacInnis, 2011).

The intended population comprises approximately 300 pre-service science teachers enrolled in the Bachelor of Education (PISMP) across three Institute of Teacher Education Malaysia (IPGM) campuses. This setting is theoretically appropriate because trainees are routinely exposed to collaborative learning strategies, making it a relevant context in which links between collaborative task features and critical thinking can be observed in early-career science education (Loes & Pascarella, 2017). For a subsequent empirical test, a stratified purposive approach across campuses and gender would be adopted; with $n \approx 300$, statistical power is adequate to detect small to medium group differences and multivariate effects at $\alpha = .05$ (Cohen, 1988).

C. Research Instruments

The research instrument used in this study is a questionnaire. The questionnaire for this study is adapted from Echiverri, L. L. (2024) and is divided into two sections representing the two sub-constructs of critical thinking. Section A measures Critical Thinking Cognitive Skills (CTCS-10), while Section B assesses Critical Thinking Dispositions. Section A: CTCS-10 contains five dimensions which are Interpretative Analysis, Inference, Evaluation, Explanation and Self-Regulation, with 2 items each dimension, resulting in 10 items in Section A. Whereas, Section B: CTD-10 contains five dimensions which are Confidence, Open Mindset, Fairness and Objectivity, Skepticism and Systematicity, with 2 items each dimension, resulting in 10 items in Section B. Overall, the questionnaire consists of 20 items and the participants will respond using a 5-point Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). Furthermore, the reliability of the instrument was previously tested by Echiverri (2024), who reported a strong reliability with a Cronbach's alpha value of 0.859, indicating that the instrument is consistent.

Table 1 Survey Instrument

Critical Thinking Cognitive Skills (CTCS)	
A1	I can correlate information gained with solving concepts and strategies.
A2	I use abstract ideas to interpret the information effectively.
A3	I can identify and ensure the needed elements to draw reasonable conclusions.
A4	I consider relevant information to deduce the consequences flowing from evidence, judgments, beliefs, opinions, or other forms of representation.
A5	I verify the referential and supportive evidence.
A6	I re-check each solving step and re-reviewing identified information.
A7	I draw conclusions based on logical reasons, supported by attaching evidence.
A8	I present well-reasoned explanations for the statement, descriptions, questions, or other forms of representation.
A9	I can self-consciously monitor my cognitive activities, the elements used in those activities, and the results produced.
A10	I can apply solutions and use gained strategies to solve problems.
Critical Thinking Dispositions (CTD)	
B1	I think I can get through any complicated problem.
B2	I persevere in handling difficult situations and challenges.
B3	I am trying to understand how the unknown thing works.
B4	I continually look for pieces of information related to solving a problem.
B5	I evaluate either my opinion or others' opinions fairly.
B6	I willingly accept the proven truth, though having a different opinion.

B7	When I see the world, I see it with a questioning mind.
B8	Although something is already set firmly, I have questions about it.
B9	When I solve or judge a problem, I utilize a collection of data by organizing it systematically.
B10	I am able to collect various factual evidence and then work out the differences, similarities or rules.

D. Data Collection

Data collection is framed as a prospective pathway for empirically testing the proposed model without displacing the primary theoretical contribution. We outline how measures of critical thinking cognitive skills and critical thinking dispositions could be operationalised among pre service science teachers while maintaining rigor, transparency, and ethical practice (Jaakkola, 2020; MacInnis, 2011).

A secure online survey platform such as Google Forms may be used to administer a structured questionnaire across multiple IPGM campuses. Online administration enables rapid deployment, automated data handling, and reduced administrative burden, but it also requires attention to coverage and nonresponse issues (Evans & Mathur, 2005; Bethlehem, 2010). To mitigate coverage error, invitation lists should be drawn from official program rosters and access should be device agnostic. The invitation will include a plain language statement describing purpose, eligibility, estimated completion time, and contact information.

E. Prospective Analysis Plan

Analyses would begin with data screening for missingness, outliers, and assumptions. Descriptive statistics will be reported for each construct and subscale: sample size (n), mean, standard deviation, standard error, 95 percent confidence intervals via t based limits, minimum, maximum, skewness, and kurtosis. Internal consistency indices (Cronbach’s alpha) will also be presented. Intercorrelations among CTCS and CTD with their dimensions will be reported with 95 percent confidence intervals. To examine gender differences across correlated outcomes, a MANOVA followed by adjusted univariate tests is appropriate; effect sizes with confidence intervals should be reported. The structural part of the model can be tested via multiple regression or path analysis/SEM. Power analysis should inform sample size planning, and reporting should include effect sizes beyond p values (Cohen, 1988; Lakens, 2013).

CONCLUSION

This study highlights that science trainee teachers perceive that collaborative learning has its impact on developing critical thinking skills effectively from the aspects of critical thinking cognitive skills and critical thinking dispositions. Various approaches which include group investigation, inquiry-based learning and online communities of practice have positively influenced the critical thinking skills among science trainee teachers. However, effective and proper guidelines of implementation should be given to teachers, which help in ensuring better preparation for future educators in fostering critical thinking among students.

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