Full research paper

EVALUATING THE IMPACT OF AI-SUPPORTED INQUIRY-BASED LEARNING ON STUDENTS' CREATIVE MATHEMATICAL PERFORMANCE, CRITICAL PROBLEM-SOLVING SKILLS, AND ATTITUDES TOWARD MATHEMATICS

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ABSTRACT

Mathematics education increasingly requires teaching approaches that strengthen students' creativity, problem-solving skills, and positive attitudes toward learning. However, limited evidence exists on the effectiveness of AI-supported inquiry-based learning in developing multiple dimensions of mathematical competence among secondary school students. This study examined the impact of AI-supported inquiry-based learning on creative mathematical performance, critical problem-solving skills, and attitudes toward mathematics. Using a quasi-experimental design, students with a mean age of 12.79 years (*SD* = 0.68) were assigned either to an experimental group receiving AI-supported inquiry-based learning or to a control group receiving conventional instruction. Data were collected through validated tests and questionnaires. The results showed that AI-supported inquiry-based learning significantly improved students' creative mathematical performance and attitudes toward mathematics compared with traditional instruction, but it did not produce a statistically significant improvement in critical problem-solving skills. Multivariate analysis confirmed a significant overall group effect, while correlation analysis showed positive relationships among all variables in both groups. Overall, the findings suggest that AI-supported inquiry-based learning mainly supports creativity and affective development, while its effect on problem-solving skills remains limited. It may also improve instructional efficiency through guided exploration, adaptive feedback, and reduced cognitive load.

KEYWORDS

AI-assisted learning, attitude toward mathematics, creative mathematical performance, critical problem-solving skills, inquiry-based learning

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Highlights

- *AI-IBL improved students' creative mathematical performance.*
- *AI-supported inquiry learning strengthened attitudes toward mathematics.*
- *Strong correlations emerged among creativity, problem-solving, and attitude.*
- *AI-IBL promoted active engagement and higher-order mathematical thinking.*

INTRODUCTION

Mathematics education has undergone a fundamental transformation as educators increasingly recognise that memorisation and direct instruction alone are insufficient for developing the competencies students need today. Inquiry-based learning (IBL) enables students to develop critical thinking, creative thinking, and deep mathematical understanding through active problem-solving activities (Niyonizera, 2023). At the same time, artificial intelligence (AI) is increasingly being used in education to create individualised learning experiences that adapt to students' needs and make learning more interactive (Haq, 2025; Khan and Begum, 2025).

Combining AI technology with inquiry-based learning offers considerable potential for educational development. AI tools allow students to explore mathematics dynamically, provide immediate feedback, and support inquiry processes that help learners address complex mathematical problems (Asghr et al., 2025). Although research indicates that AI-based interventions can improve critical thinking and problem-solving abilities (Asghr et al., 2025), less is known about how AI-supported inquiry-based learning affects students' mathematical creativity and attitudes toward mathematics in quasi-experimental studies. Research shows that inquiry-based learning models can contribute to the development of students' creative and critical thinking abilities (Suherman et al., 2025), while AI-based educational tools show potential for enhancing complex mathematical thinking (Kim et al., 2025). However, limited empirical evidence has examined how AI-supported inquiry-based learning influences students' creative mathematical performance, critical problem-solving skills, and attitudes toward mathematics compared with traditional instructional approaches (Khan and Begum, 2025). This issue is particularly relevant in Indonesia, where strengthening students' higher-order thinking skills remains a key educational priority in response to persistent challenges in mathematics achievement and creativity development. Indonesia is also representative of many developing education systems that are undergoing digital transformation while continuing to struggle with fostering creativity and problem-solving competence in mathematics learning. Therefore, examining instructional innovations such as AI-supported inquiry-based learning in this context has both local significance and broader relevance for similar educational settings globally.

Evidence from the Programme for International Student Assessment (PISA) highlights these challenges. In PISA (2024), Indonesia was among the countries with the lowest performance in creative thinking, with a substantial proportion of students failing to reach baseline proficiency levels (59.0%). Similar patterns of underperformance were also observed across several other participating countries, particularly in developing and emerging education systems. This indicates that low levels of creative thinking in mathematics and problem-solving are not unique to Indonesia, but reflect a broader global issue. Figure 1 illustrates the distribution of students below baseline proficiency in creative thinking among low-performing participating countries.

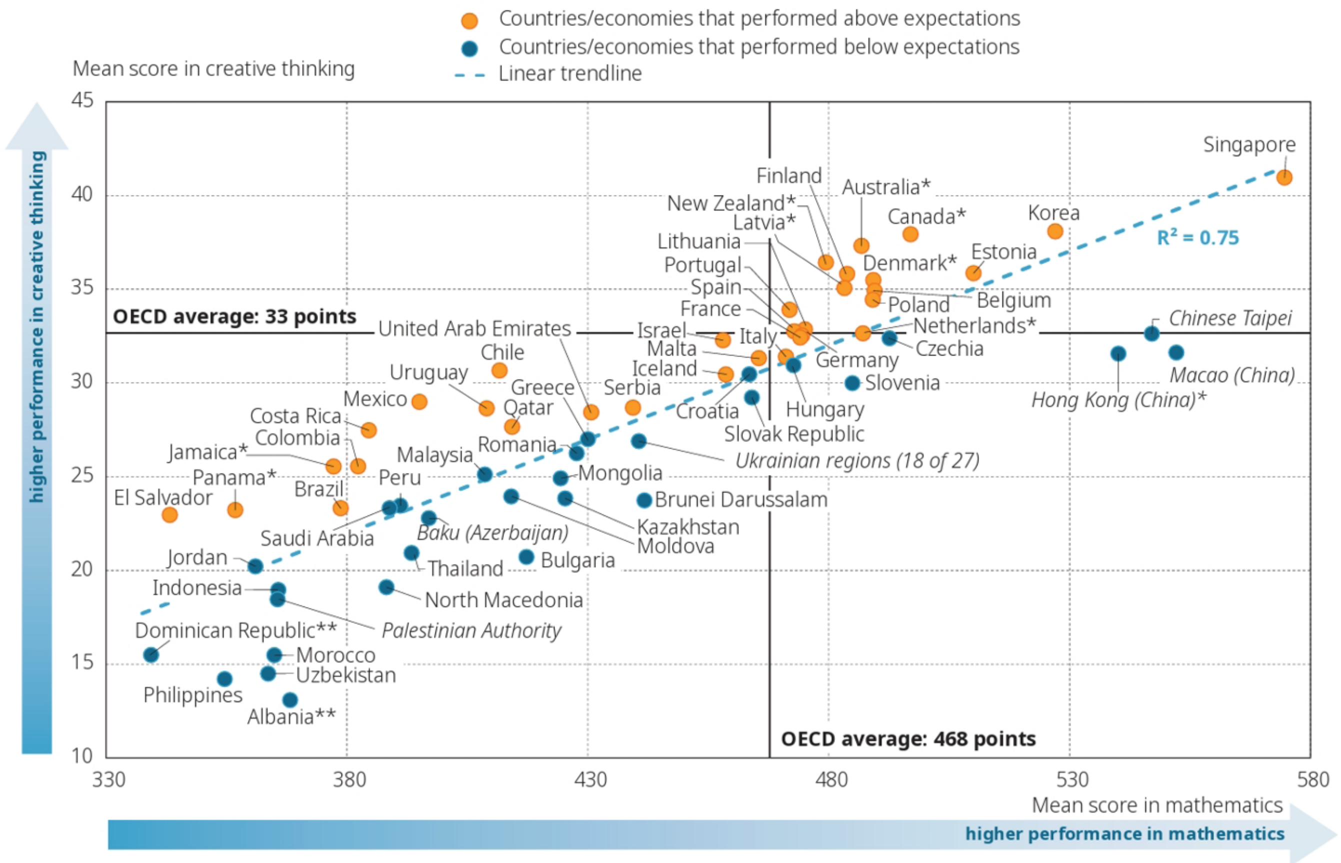

Figure 1: Mean scores in creative thinking and mathematics performance across countries participating in PISA 2024 (Source: OECD, (2024))

These developments reflect the growing integration of inquiry-based pedagogy and artificial intelligence in mathematics education, offering new opportunities to enhance how students learn and engage with mathematical ideas. At the same time, stronger empirical evidence is needed on how this integration works in practice, particularly in relation to students' creative mathematical performance, critical problem-solving skills, and attitudes toward mathematics compared with traditional instruction. This gap is especially relevant in education systems that are undergoing rapid digital transformation while continuing to face challenges in developing higher-order mathematical thinking. Therefore, this study systematically examined the effects of AI-supported inquiry-based learning on students' creative mathematical performance, critical problem-solving skills, and attitudes toward mathematics using a quasi-experimental design. The study addressed the following three research questions:

1. Does AI-supported inquiry-based learning enhance students' creative mathematical performance compared to traditional instruction?
2. What is the impact of AI-supported inquiry-based learning on students' critical problem-solving skills?
3. How does participation in AI-supported inquiry-based learning affect students' attitudes toward mathematics?

LITERATURE REVIEW

Foundation of Inquiry-Based Learning

Inquiry-based learning (IBL) is grounded in constructivist educational theories, which posit that learners actively construct knowledge rather than passively receive information. Constructivist principles suggest that knowledge develops through meaningful experiences that encourage exploration, questioning, and discovery. This perspective shifts the teacher's role from that of a transmitter of facts to a facilitator who guides students through active learning processes. In this regard, IBL emphasises student-centred discovery, enabling learners to explore complex mathematical problems and develop meaningful understanding through firsthand investigation rather than rote memorisation or procedural repetition (Niyonizera Daniel, 2023).

The effectiveness of IBL depends on adequate scaffolding and guided inquiry structures, which ensure that students are supported while also being challenged to engage deeply with the material. Scaffolding, a concept introduced by Vygotsky and later developed in educational psychology, refers to temporary support provided to learners to help them attain higher levels of understanding and skill mastery. In inquiry-based settings, such support may include probing questions, problem-solving frameworks, and conceptual clarification, all of which are gradually reduced as learners become more proficient (Anugrah et al., 2025). This type of scaffolding can build students' confidence and autonomy, both of which are essential for sustaining engagement and advancing cognitive skills.

The implementation of IBL in mathematics education has been shown to provide significant benefits, including the development of creativity, critical thinking, and problem-solving capabilities. Students who participate in inquiry-oriented mathematics instruction demonstrate stronger abilities to generate innovative solutions, analyse problems from multiple perspectives, and apply logical reasoning in novel contexts. Empirical research linking inquiry-based methodologies with improvements in scientific and mathematical thinking supports the value of this approach in complex domains such as mathematics (Engeln et al., 2013; Wale & Bishaw, 2020). By promoting exploration and reflection, IBL fosters curiosity and cognitive flexibility that align with the demands of 21st-century learning.

Despite these advantages, implementing IBL may also present several instructional challenges. Inquiry-oriented learning activities often require more classroom time and more careful instructional planning than conventional approaches (Kolbe et al., 2020). In addition, some students, particularly those with limited prior knowledge, may initially experience difficulty when engaging in open-ended inquiry tasks. Studies grounded in cognitive load theory suggest that inquiry activities are most effective when accompanied by appropriate scaffolding and structured guidance from teachers (Kalyuga & Singh, 2016). Therefore, the success of IBL depends not only on student exploration but also on the quality of instructional support provided throughout the learning process.

The importance of artificial intelligence in mathematics education

The integration of AI into teaching draws on sociocultural and constructivist theories, which suggest that meaningful learning is best achieved when instruction is tailored to learners' needs and actively involves students in constructing understanding. The personalisation capacity of AI in education enables content and pacing to be adapted to student responses, making it possible to provide differentiated instruction that is difficult to achieve in traditional classroom settings.

The integration of artificial intelligence into educational scaffolding can enhance learning by providing adaptive, personalised interactions that respond to individual learners' needs in real time. AI-driven systems can analyse student responses, detect error patterns, and tailor feedback to optimise learning pathways. This adaptive capability improves personalisation by adjusting difficulty levels, offering hints, or providing exploratory prompts based on each learner's performance and engagement, thereby supporting a more efficient and individualised learning experience (Mohsin Ayaz Khan, 2025).

In addition to basic adaptation, AI can serve as cognitive and metacognitive scaffolding, supporting learners not only in mastering content but also in regulating their own learning processes. This approach can promote metacognitive awareness by encouraging students to reflect on their problem-solving strategies, plan their approaches, and evaluate outcomes critically. Such cognitive support may enhance self-regulation and motivation, empowering learners to take ownership of their learning and persist in challenging tasks (Asghr et al., 2025). Furthermore, AI's capacity to monitor learning progress and provide formative feedback is closely aligned with pedagogical theories that advocate ongoing assessment and personalised instruction (Minjung Kim, 2025).

The intersection of AI technology and educational pedagogy has given rise to an emerging hybrid model in which AI tools complement teacher-led inquiry by addressing gaps in real-time support and increasing the scalability of individualised learning. This synergy represents a significant advancement in personalised inquiry support, as AI can enhance the teacher's capacity to scaffold diverse learning trajectories, particularly in complex, open-ended mathematical activities. Integrating AI with pedagogical frameworks may therefore strengthen the effectiveness of inquiry-based learning in achieving diverse and meaningful educational outcomes.

Although AI technologies offer considerable potential for personalised learning and adaptive feedback, several challenges should also be considered in educational implementation (Strielkowski et al., 2025). AI-generated responses may occasionally provide oversimplified explanations or inaccurate reasoning in complex mathematical contexts (Sirnoorkar et al., 2024). Moreover, excessive reliance on AI assistance could reduce opportunities for students to develop deep reasoning and reflective thinking skills independently (Zhai et al., 2024). Nevertheless, recent studies emphasise that these limitations can be minimised when AI is used as a supportive learning tool under appropriate teacher supervision and within an inquiry-based instructional design, rather than as a replacement for active student thinking and classroom interaction (Yeh, 2025).

The role of inquiry in supporting creativity and critical thinking

IBL can be regarded as a dynamic pedagogical approach that fosters creativity and critical thinking by allowing students to engage actively in the learning process. In IBL environments, students are encouraged to pose questions, explore, and investigate in order to construct knowledge, thereby developing inquiry and problem-solving skills (Smith et al., 2022). Research indicates that IBL enhances critical thinking by training students in essential cognitive skills such as problem formulation, data collection, evaluation, and information synthesis (Kadir & Satriawati, 2017; Wale & Bishaw, 2020). This enhancement is especially evident when guided inquiry-based modules are used, as they have been shown to improve students' capacity to think critically and apply learning in context (Alqarni, 2025; Wale & Bishaw, 2020). Moreover, empirical studies demonstrate that IBL can deepen students' understanding of scientific processes, stimulating critical thinking and an innovative mindset that are essential for solving complex, real-world problems (Dagys, 2017; Syahgiah et al., 2023).

Furthermore, IBL can substantially strengthen students' creativity through its emphasis on exploration and self-directed learning. This pedagogical approach encourages students to move beyond conventional frameworks and continually refine their ideas and methods in response to empirical findings and learning experiences (Sam, 2024). For instance, the implementation of IBL in science education has shown that students who engage in inquiry-oriented tasks develop not only scientific knowledge but also a creative disposition that enables them to imagine new possibilities and solutions (Umbara et al., 2017; Wale & Bishaw, 2020). This instructional approach is also consistent with constructivist educational theories, which propose that knowledge is constructed through experience and interaction, thereby empowering students to formulate original ideas and creatively address challenges (Baldock & Murphrey, 2020; Thoron & Burleson, 2014). Overall, inquiry-based learning creates an academic environment that supports the development of creativity and critical thinking skills, preparing students for both academic tasks and real-world applications.

AI-enabled technologies and attitudes toward mathematics

The implementation of AI-enabled technologies in mathematics education can substantially influence students' attitudes toward the subject. As educators increasingly adopt AI-supported personalised learning methods, students have more opportunities to receive individualised support, which can enhance their performance and foster more positive attitudes toward mathematics (Opesemowo & Ndlovu, 2024; Orhani, 2021). AI technologies can diagnose individual learning challenges and tailor instructional strategies accordingly, leading to improved engagement and comprehension in mathematics (Opesemowo & Ndlovu, 2024; Orhani, 2021). This tailored approach addresses students' distinct learning needs, potentially reducing anxiety and enhancing self-efficacy in mathematics (Wang, 2025). Studies have also indicated that integrating AI into inquiry-based creative learning environments may improve academic performance, suggesting significant potential for transforming students' perceptions of the subject (Yeh, 2025). Furthermore, existing research indicates a relationship between positive attitudes toward AI and mathematics, suggesting that students' perceptions of AI technologies can significantly influence their feelings about mathematics learning (Bation & Pudan, 2024; Hussain, 2020). For instance, the use of AI-based applications can enhance the effectiveness of educational methods and support the achievement of learning objectives, thereby creating an environment that fosters positive attitudes toward mathematics (Aykan, 2024). The impact of these technologies extends beyond academic performance by cultivating a mindset that values iterative problem-solving and critical thinking (Çela et al., 2024). These skills are essential in mathematics. AI-enabled technologies therefore influence not only how mathematics is taught, but also how students engage with the subject, encouraging deeper involvement with mathematical concepts and applications in their academic lives (Hwang & Son, 2021; Shakya & Maharjan, 2023).

METHODS

Participants

The research sample consisted of 120 Grade 8 students (79 females and 41 males; mean age = 12.79 years, SD = 0.68) drawn from two public middle schools in Bandar Lampung City, Indonesia. The two schools were selected because they had comparable socioeconomic and educational contexts, as both were urban public schools with similar institutional characteristics and resource availability. However, no individual-level matching procedure was conducted because of the intact-class quasi-experimental design and practical constraints in school settings. Instead, class equivalence was approached at the school level by selecting schools with broadly similar academic and contextual profiles (Suherman et al., 2025). One intact Grade 8 class from each school participated in the study (n = 60 per group). The experimental group receiving AI-supported IBL consisted of 41 females and 19 males, while the control group receiving traditional instruction included 38 females and 22 males. Before data collection, institutional and school permissions were secured, and informed consent was obtained from all participants.

Design

A pretest–posttest non-equivalent groups design was used. The experimental group engaged in mathematics lessons centred on inquiry-based activities and supported by an AI tool (ChatGPT), which provided adaptive feedback, hints, and scaffolding during problem-solving. The control group received teacher-led lessons covering the same topics and problem sets, but without inquiry tasks or AI support (Chaleelpliam et al., 2023). Examples of the experimental activities are presented in Table 1.

Activity Topic	Curricular Focus	AI & Inquiry Themes	Specific AI-IBL Activities
Introduction to Geometry	Understanding basic geometry concepts; distinction between plane and solid figures	Inquiry-based learning: observation and classification	Group discussion: identify geometric shapes in daily life Brainstorming activity: classify classroom objects into plane vs. solid figures
Plane Figures: Square & Rectangle	Properties of squares and rectangles; perimeter and area	AI-assisted visualization: interactive geometric tools	Teacher demonstration with visual aids Individual practice with AI geometry apps to calculate perimeter and area
Plane Figures: Parallelogram, Rhombus, Trapezoid	Properties, perimeter, and area calculation	Inquiry and AI: exploring properties of less common shapes	Group discussion on common mistakes Worksheet exercises using AI-assisted drawing tools for shapes
Introduction to Triangles & Types	Classification of triangles by sides and angles	Inquiry: hands-on exploration	Hands-on activity: creating triangles with paper/rulers Visual examples to classify triangles
Properties of Triangles	Sum of angles, relationships between sides and angles	Inquiry: problem-solving	Solve basic angle problems in groups Real-life examples of triangles
Basic Pythagoras Theorem	Applying Pythagoras theorem in right triangles	Inquiry and AI: calculation support	Identify right triangles in images or diagrams Use AI tools to calculate missing sides ($a^2 + b^2 = c^2$)
Triangles in Real Life Applications	Application of triangles in architecture, art, engineering	AI & inquiry: real-world problem identification	Virtual tour / photo analysis of buildings with triangles Project: students diagram triangles in their environment
Review & Assessment	Integration of all concepts: plane figures, triangles, and calculations	Inquiry-based assessment; AI-assisted feedback	Integrative exercises combining perimeter, area, triangle identification, Pythagoras AI tools for instant feedback on calculations

Table 1: AI-IBL Activities (Source: own elaboration)

This study included only Grade 8 students because students at this developmental stage are generally considered capable of engaging in higher-order thinking processes, including abstract reasoning, problem-solving, and creative mathematical thinking. According to Piaget's theory of cognitive development, early adolescents typically begin transitioning into the formal operational stage, which enables more logical and hypothetical reasoning (Piaget, 1976). Previous mathematics education research has also shown that middle school students possess sufficient cognitive readiness to participate in inquiry-based and problem-solving-oriented learning activities that require analytical and creative thinking (Belland et al., 2011; Bicer et al., 2021). At this level, students have usually acquired foundational knowledge of geometry, making them suitable for examining the effects of AI-supported inquiry-based learning on mathematical skills. Limiting participants to a single grade also helped ensure relatively similar cognitive and educational backgrounds, thereby reducing variability associated with developmental and curricular differences.

The assignment of classes to the experimental and control conditions was conducted using a lottery-based procedure, in which the first class drawn was assigned to the experimental group and the second to the control group. However, this procedure was implemented within practical constraints imposed by school scheduling. Because it was not feasible to create new classes or reorganise existing timetables, the selection of participating classes was coordinated with school administrators to ensure compatibility with academic schedules and teacher availability. To strengthen the internal validity of the study, efforts were made to ensure that the selected classes were comparable in terms of prior academic exposure, curriculum coverage, and learning experiences before the intervention.

In the experimental class, instruction was organised around small-group activities, with students grouped according to age, interests, developmental readiness, and skill levels. These groups engaged in collaborative AI-IBL activities, such as exploring two- and three-dimensional shapes, calculating areas and perimeters, and constructing and analysing triangles. Research indicates that group-based, inquiry-oriented instruction is often more effective than traditional one-on-one teaching approaches. In contrast, the control class followed the standard curriculum, which relied on teacher-led lectures, individual exercises, and minimal hands-on problem-solving, thereby providing a baseline for comparison. The study's experimental design is shown in Figure 2.

Sessions began at around 8:30 a.m. and lasted 60–90 minutes, typically starting with a brief physical activity to help students release energy and focus on learning. After completing the nine-week AI-IBL geometry programme, students' creative and critical thinking skills were assessed, and outcomes from the experimental and control groups were compared.

Finally, after the intervention, students completed two types of post-assessment measures. First, a post-test was administered to evaluate students' creative mathematical performance and critical problem-solving skills, with a duration of approximately 45–60 minutes. Second, a follow-up questionnaire was administered to assess students' attitudes toward mathematics. The questionnaire was completed individually in a quiet setting and took approximately 5–10 minutes per student.

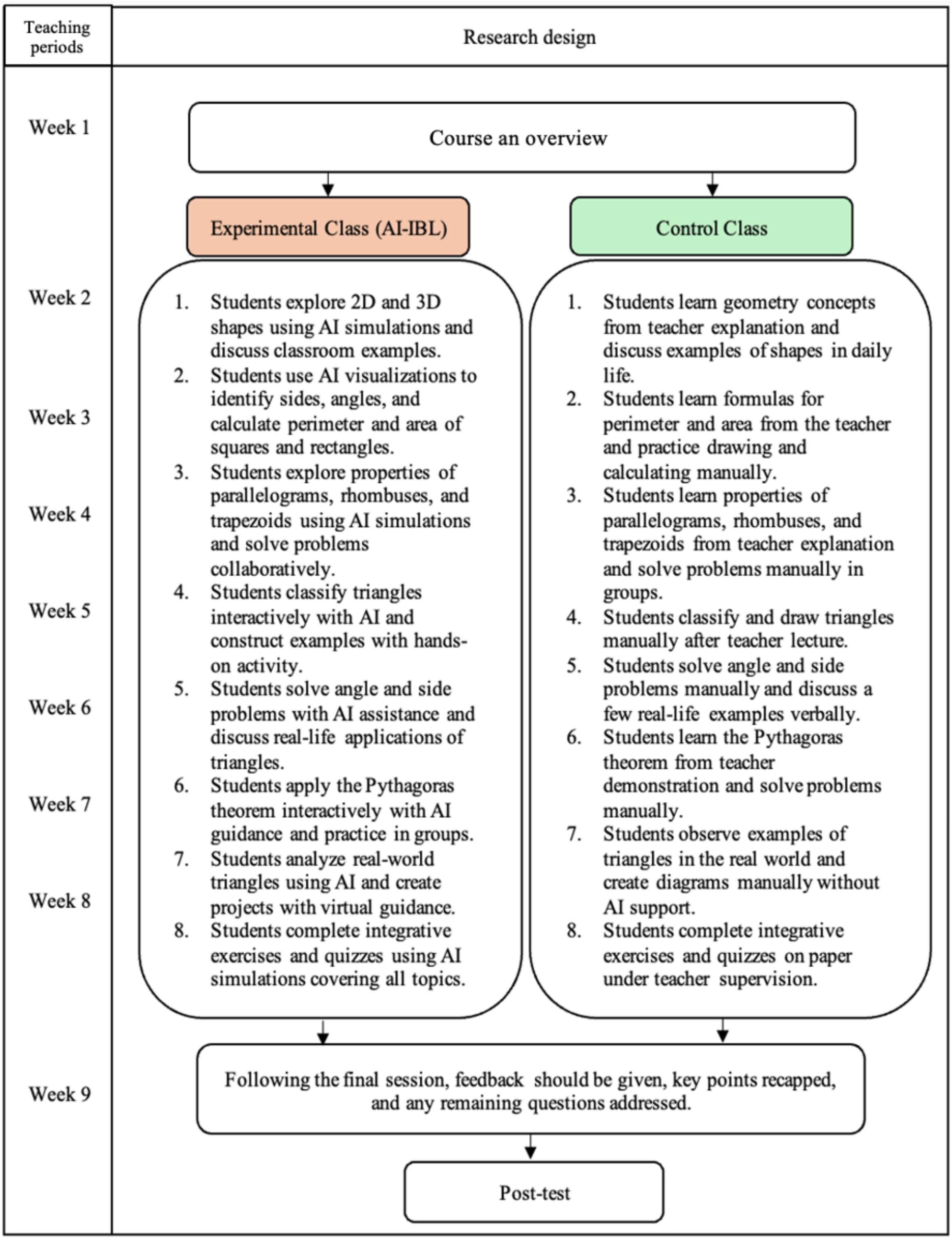

Figure 2: Research procedure (Source: modified from Suherman et al. (2025))

Instrument

The instruments used in this study consisted of a questionnaire and two separate essay-based tests. The questionnaire assessed students' attitudes toward mathematics. The first essay test measured creative mathematical performance (CMP) and consisted of five open-ended items. The second essay test measured critical problem-solving (CPS) and consisted of four open-ended items. Both tests required students to solve non-routine mathematical problems and were adapted from Suherman and Vidákovich (2025). An example of the essay test items is presented in Figure 3. Students' responses were scored using a five-point analytic rubric (1–5) to assess both CMP and CPS. A score of 1 indicated very limited or incorrect responses with no valid mathematical reasoning, while a score of 2 reflected minimal understanding with largely incorrect or incomplete solutions. A score of 3 represented partially correct responses with some appropriate steps but noticeable errors in reasoning or computation. A score of 4 indicated mostly correct and logically structured solutions with minor errors, whereas a score of 5 represented fully correct, well-reasoned, and complete solutions demonstrating strong mathematical understanding. For CMP, this included originality of strategies, while for CPS it reflected strong logical justification and problem-solving accuracy.

The triangle is designed by Tapis Lampung ornament with *Jung Sarat* motif. The triangle is a right triangle with legs 8 and 6. The vertices are at the points A(0,0), B(0,6), and C(0,8). The red line segment is perpendicular to hypotenuse. Find the length of the red line segment.

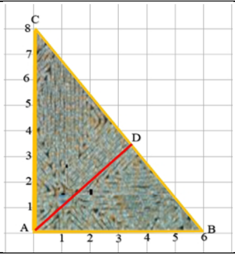

Figure 3: An example of a creative and critical thinking test (Source: adapted from Suherman and Vidákovich (2025))

The Attitude toward Mathematics questionnaire was adapted from Suherman and Vidákovich (2022) and included five statements, each with five response options. Scores were assigned using a Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Sample items included statements such as "I am really good at math" and "I feel confident in my abilities to solve mathematics problems."

In this study, the validity and reliability of the instruments were evaluated. The critical thinking test initially included five items; however, one item had a factor loading below 0.4 and was therefore removed, leaving four valid items. The creative thinking test consisted of five items, and the Attitude toward Mathematics questionnaire also contained five items. A summary of the instruments' validity and reliability is presented in Table 2.

Items	Loading factors	Cronbach's alpha (standardized)	Composite reliability (rho_c)	Average variance extracted (AVE)
Creative mathematical performance (CMP)		0.921	0.924	0.703
CMP1	0.700			
CMP2	0.798			
CMP3	0.880			
CMP4	0.870			
CMP5	0.925			
Critical problem-solving (CPS)		0.710	0.728	0.401
CPS1	0.651			
CPS2	0.829			
CPS3	0.524			
CPS4	0.469			
Attitude toward Mathematics (ATM)		0.903	0.902	0.651
ATM1	0.767			
ATM2	0.808			
ATM3	0.856			
ATM4	0.822			
ATM5	0.780			

Table 2: Psychometric evaluation of the instruments (Source: own elaboration)

Data analysis

The data were analysed using both descriptive statistics (means and standard deviations) and inferential statistics to compare groups and report effect sizes, primarily using SPSS 31. SPSS was used to conduct correlation analyses, independent samples t-tests, and MANOVAs to examine differences between the experimental and control groups across multiple dependent variables. SmartPLS 4 was used to assess the psychometric properties of the instruments, while R software was used to generate visualisations illustrating students' performance across all variables in both groups.

RESULTS

Table 3 presents the descriptive statistics and correlation analysis among CMP, CPS, and ATM for both groups. The experimental group showed slightly higher mean scores across all variables (CMP = 3.63, CPS = 3.36, ATM = 3.56) than the control group (CMP = 3.22, CPS = 3.17, ATM = 3.14), with comparable levels of dispersion, as indicated by standard deviations ranging from 0.77 to 0.95. Skewness and kurtosis values further confirmed that the data approximated a normal distribution in both groups.

The correlation analysis revealed strong and statistically significant positive relationships among all variables in both groups. However, the control group consistently demonstrated slightly stronger interrelationships among CMP, CPS, and ATM (r = 0.720 to 0.896) than the experimental group (r = 0.688 to 0.892). This indicates that the associations among cognitive and affective variables were more tightly connected under traditional learning conditions, whereas the AI-IBL intervention resulted in slightly weaker interdependencies among the constructs.

Group	Variable	M	SD	Skewness	Kurtosis	CMP	CPS	ATM
Experimental	CMP	3.63	0.89	-0.32	-0.23	-		
	CPS	3.36	0.92	-0.46	-0.33	0.718**	-	
	ATM	3.56	0.77	-0.51	-0.72	0.892**	0.688**	-
Control	CMP	3.22	0.95	-0.16	-0.23	-		
	CPS	3.17	0.77	0.06	-0.33	0.761**	-	
	ATM	3.14	0.93	0.06	-0.72	0.896**	0.720**	-

*Note: **. Correlation is significant at the 0.01 level (2-tailed).*

Table 3: Summary of descriptive statistics and correlations among groups (Source: own elaboration)

Regarding data normality, following Kline (2015), skewness values within ±3 and kurtosis values within ±10 indicate acceptable normal distribution. In this study, skewness values ranged from -0.51 to 0.06 across both experimental and control groups, while kurtosis values ranged from -0.72 to -0.23. These results suggest that all variables (CMP, CPS, and ATM) demonstrated acceptable levels of normality, indicating that the data distributions did not substantially deviate from normality assumptions.

Homogeneity of variance was examined using Levene's test. The results indicated that the assumption of equal variances was met for all variables, including CMP (F = 0.000, p = 0.986), CPS (F = 1.101, p = 0.296), and ATM (F = 1.714, p = 0.193). Because all p-values exceeded the 0.05 threshold, the homogeneity assumption was satisfied, supporting the use of independent samples t-tests with equal variances assumed.

Multicollinearity was examined using Pearson correlation coefficients among the dependent variables. The results indicated strong positive relationships between CMP, CPS, and ATM, with correlation values ranging from r = 0.695 to r = 0.898. Although the correlation between CMP and ATM was relatively high, it did not exceed the critical threshold of 0.90, suggesting that multicollinearity was not severe and that the variables could be retained for multivariate analysis.

Table 4 presents the results of the multivariate tests examining the effect of group (experimental vs. control) on the combined dependent variables (CMP, CPS, and ATM). The intercept showed a highly significant effect across all dependent variables (Pillai's Trace = 0.948, $F(3,116)$ = 705.94, $p < 0.001$, η^2 = 0.948), reflecting the overall mean levels of the measures. More importantly, the group effect was statistically significant at the multivariate level (Pillai's Trace = 0.065, $F(3,116)$ = 2.694, p = 0.049, η^2 = 0.065), indicating a significant difference between the experimental and control groups when the dependent variables were considered together. The effect size (η^2 = 0.065) suggests a small-to-moderate practical impact of the intervention. This finding implies that the instructional approach, namely the AI-IBL intervention, influenced students' creative mathematical performance, problem-solving skills, and attitudes toward mathematics collectively, warranting further investigation through follow-up univariate tests for each variable.

Effect	Value	*F*	Hypothesis *df*	Error *df*	*Sig.*	η^2
Intercept						
Pillai's Trace	0.948	705.936	3	116	<0.001	0.948
Wilks' Lambda	0.052	705.936	3	116	<0.001	0.948
Hotelling's Trace	18.257	705.936	3	116	<0.001	0.948
Roy's Largest Root	18.257	705.936	3	116	<0.001	0.948
Group						
Pillai's Trace	0.065	2.694	3	116	0.049	0.065
Wilks' Lambda	0.935	2.694	3	116	0.049	0.065
Hotelling's Trace	0.070	2.694	3	116	0.049	0.065
Roy's Largest Root	0.070	2.694	3	116	0.049	0.065

Table 4: Multivariate test results (Source: own elaboration)

To evaluate the effects of the instructional intervention on students' outcomes, independent samples t-tests were conducted for CMP, CPS, and ATM, as presented in Table 5. The results showed that students in the experimental group achieved significantly higher CMP scores (M = 3.63, SD = 0.90) than those in the control group (M = 3.22, SD = 0.95), t(117.579) = 2.386, p = 0.019, d = 0.436, indicating a moderate effect of the AI-IBL approach on creative mathematical performance. Similarly, students in the experimental group reported significantly higher ATM scores (M = 3.56, SD = 0.77) than the control group (M = 3.14, SD = 0.93), t(114.257) = 2.702, p = 0.008, d = 0.493, suggesting a moderate positive effect of the intervention on attitudes toward mathematics. In contrast, no statistically significant difference was found in CPS between the experimental group (M = 3.36, SD = 0.92) and the control group (M = 3.17, SD = 0.77), t(114.640) = 1.213, p = 0.228, d = 0.221, suggesting that the intervention had a limited effect on critical problem-solving skills. Overall, these findings indicate that the AI-IBL instructional approach was most effective in improving creative mathematical performance and students' attitudes toward mathematics, while its impact on critical problem-solving skills remained relatively small. The distribution of students' performance across variables is illustrated in Figure 4.

Variables	Experimental *M* (*SD*)	Control *M* (*SD*)	*t*	*df*	*p*	Cohen's *d*
CMP	3.63 (0.90)	3.22 (0.95)	2.386	117.579	0.019	0.436
CPS	3.36 (0.92)	3.17 (0.77)	1.213	114.640	0.228	0.221
ATM	3.56 (0.77)	3.14 (0.93)	2.702	114.257	0.008	0.493

Table 5: Summary of the independent sample *t*-test (Source: own elaboration)

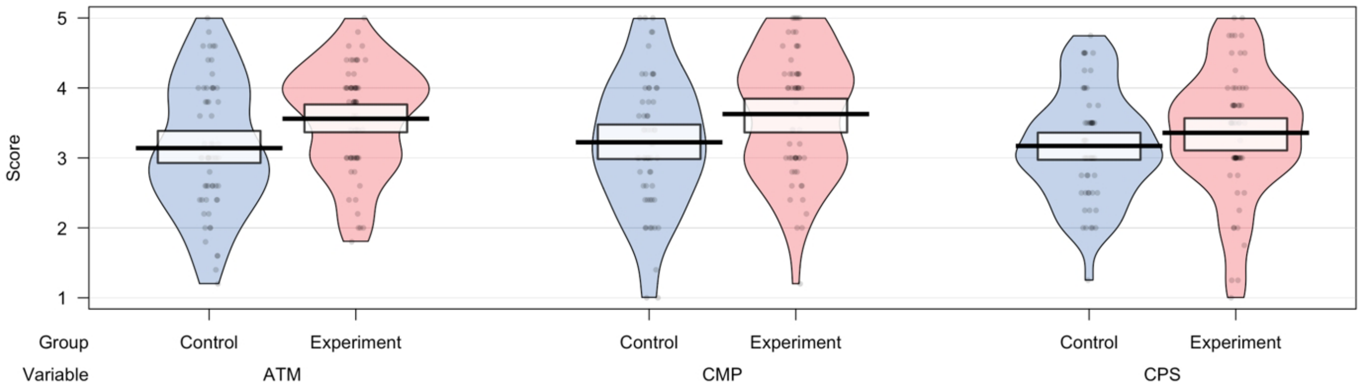

Figure 4: Students' performance among variables (Source: R software output)

DISCUSSION

The results of this study demonstrate that the AI-IBL instructional approach had a positive impact on students' mathematical learning outcomes, particularly attitudes toward mathematics and creative mathematical performance, with the strongest effect observed in the affective domain. Students in the experimental group consistently scored higher than those in the control group across all measured variables. The most pronounced improvement was found in attitudes toward mathematics, indicating that AI-supported inquiry-based learning plays a particularly important role in shaping students' motivation, interest, and emotional engagement in mathematics learning. This was followed by improvements in creative mathematical performance, where students in the experimental group demonstrated greater originality, flexibility, and diversity in solution generation compared with traditional instruction. These findings suggest that AI tools may support divergent thinking processes by scaffolding exploration and prompting multiple solution pathways (Guo et al., 2025; Wei et al., 2025).

The descriptive statistics and correlation analysis showed that CMP, CPS, and ATM were strongly interrelated in both groups. However, slightly stronger interrelationships were observed in the control group than in the experimental group, suggesting that in traditional learning environments, cognitive and affective dimensions tend to be more tightly coupled. In contrast, the AI-IBL condition appeared to promote a more differentiated pattern of relationships among constructs, indicating a possible shift toward more independent development of cognitive and affective domains. This pattern aligns with previous research indicating that inquiry-based learning environments can simultaneously support creativity, problem-solving, and positive attitudes in mathematics education (Bhardwaj et al., 2025; Conradty & Bogner, 2019; Engeln et al., 2013; Huang, 2022).

In contrast, no statistically significant improvement was found in critical problem-solving skills, indicating that the intervention did not produce a measurable effect on this domain. Although students in the experimental group showed slightly higher mean performance, the difference was not sufficient to indicate a meaningful impact. This suggests that, while AI-supported inquiry-based learning may facilitate exploration and idea generation, the development of structured and evaluative problem-solving skills likely requires more sustained instructional scaffolding, explicit metacognitive guidance, and longer-term practice beyond a short-term intervention (Hidayatullah et al., 2024; Lai, 2025).

At the multivariate level, the group effect was significant, indicating that the intervention influenced students collectively across the three dependent variables. Consistent with the univariate results, this finding suggests that the instructional approach primarily affected affective and creative dimensions, while contributing less to structured problem-solving performance. Although the overall effect size was modest, the result confirms that instructional models integrating AI and inquiry-based strategies can produce measurable changes in students' learning outcomes. This aligns with prior studies showing that digital and interactive pedagogical tools can enhance engagement and cognitive development in mathematics education (Cirneanu & Moldoveanu, 2024; Engelbrecht & Borba, 2024).

The findings further suggest that AI-supported inquiry-based learning can foster students' creative mathematical performance and positive attitudes toward mathematics by promoting active exploration, idea generation, and interactive learning experiences. Inquiry-oriented environments supported by generative AI encourage students to engage in open-ended reasoning (Li et al., 2025), receive immediate feedback (Dong et al., 2026), and explore multiple solution pathways (Lee & So, 2025), which may strengthen mathematical creativity and learning engagement. Recent studies have similarly reported that AI-assisted mathematics learning environments contribute positively to students' creativity, motivation, and attitudes (Akosah, 2025; B. Liu et al., 2026; J. Liu et al., 2025) by facilitating adaptive support and reflective learning processes. However, the limited improvement in critical problem-solving skills indicates that higher-order reasoning development requires more sustained scaffolding, metacognitive regulation, and deeper conceptual engagement beyond short-term AI integration.

However, the results warrant several caveats. Not all students experienced the intervention in the same way, as some lower-achieving learners reported initial difficulty adapting to self-directed inquiry even with AI support. Teacher facilitation and peer collaboration appeared to play an important moderating role in supporting student engagement. Although this limitation is consistent with findings from other technology-enhanced inquiry-based studies, it highlights the importance of blended instructional designs that combine digital tools with structured teacher guidance (Supriadi et al., 2025). Furthermore, attitudes toward mathematics remain influenced by broader contextual and socio-emotional factors, including classroom climate, teacher beliefs, and school culture (Hidayatullah & Csíkos, 2023, 2025; Suherman & Vidákovich, 2024).

These findings have important practical implications. In the context of increasing digital transformation in education, fostering positive attitudes and creative thinking in mathematics is essential for preparing students to face complex problem-solving demands. The study highlights the value of AI-supported inquiry-based approaches that encourage active participation, collaboration, and exploration while also enhancing instructional efficiency through timely feedback, adaptive scaffolding, and optimised learning processes. Teachers are therefore encouraged to integrate AI-supported inquiry activities within structured instructional design, ensuring a balance between exploratory learning and guided mathematical reasoning.

LIMITATIONS AND FUTURE RESEARCH

Although this study provides evidence supporting the efficacy of AI-supported inquiry-based mathematics instruction, its quasi-experimental design means that residual selection bias may persist because intact classes were used without random assignment or statistical covariate adjustment at baseline. Because the groups were not randomly assigned, causality should be interpreted with caution. In addition, the intervention occurred over one academic term, so longer-term effects and sustainability remain unknown. Future research should examine the scalability of AI-IBL across diverse school settings, grade levels, and demographic backgrounds. Longitudinal studies could further clarify the persistence of the observed gains, and qualitative investigations may help explain the experiences of lower-achieving or differently motivated students. Studies comparing different AI tools or levels of inquiry complexity would also add valuable nuance to the field.

CONCLUSION

This study demonstrates that AI-supported inquiry-based learning contributes positively to students' creative mathematical performance and attitudes toward mathematics compared with traditional instruction. The findings underscore the value of combining technological innovation with inquiry-driven pedagogy in mathematics education, particularly as schools seek to prepare students for the demands of a rapidly evolving, knowledge-based society. Although students exposed to the AI-supported approach tended to show more favorable critical problem-solving outcomes, the evidence suggests that its influence in this area may be less pronounced and warrants further investigation. Educators and policymakers should therefore consider the strategic use of AI to scaffold inquiry learning, enhance learning effectiveness and instructional efficiency, and address issues of equity and differentiation to ensure that all students benefit from these advances. In addition, AI integration may contribute to more efficient learning processes by providing immediate feedback and reducing delays in concept clarification during classroom activities.

REFERENCES

Akosah, E. F. (2025) 'AI-Assisted Collaborative Learning in Mathematics Education: A Qualitative Approach', *International Journal of Technology in Education and Science*, Vol. 9, No. 3, pp. 416–433. https://doi.org/10.46328/ijtes.634

Alqarni, A. (2025) 'Artificial Intelligence-Critical Pedagogic: Design and Psychologic Validation of a Teacher-Specific Scale for Enhancing Critical Thinking in Classrooms', *Journal of Computer Assisted Learning*, Vol. 41, No. 3, p. e70039. https://doi.org/10.1111/jcal.70039

Anugrah, S., Jalinus, N., Syahril, S., Supendra, D. and Anggraini Austin, D. (2025) 'Enhancing High-Order Thinking Skills in Computer Courses through theImplementation of the Inquiry Learning and Virtual Laboratory in Higher Education', *TEM Journal*, Vol. 14, No. 2, 1466–1477. https://doi.org/10.18421/TEM142-47

Asghr, K., Munawar, U. and Ullah, N. (2025) 'Examining the effect of ai tools on critical thinking and problem solving skills among higher education students', *Gomal University Journal of Research*, Vol. 41, No. 1, pp. 105–114. https://doi.org/10.51380/gujr-41-01-10

Aykan, A. (2024) 'The Impact of the Lesson Study Model on Students' Mathematics Achievement and Attitudes: A mixed-Methods Research', *International Journal for Lesson and Learning Studies*, Vol. 13, No. 4, pp. 397–415. https://doi.org/10.1108/ijlls-05-2024-0106

Baldock, K. D. and Murphrey, T. P. (2020) 'Secondary Students' Perceptions of Inquiry-Based Learning in the Agriculture Classroom', *Journal of Agricultural Education*, Vol. 61, No. 1, pp. 235–246. https://doi.org/10.5032/jae.2020.01235

Bation, N. D. and Pudan, J. C. (2024) 'Exploring the Correlation Between Students' Attitudes Towards AI and Their Learning Outcomes', *International Journal of Social Science and Human Research*, Vol. 07, No. 02. https://doi.org/10.47191/ijsshr/v7-i02-45

Belland, B. R., Glazewski, K. D. and Richardson, J. C. (2011) 'Problem-based learning and argumentation: Testing a scaffolding framework to support middle school students' creation of evidence-based arguments', *Instructional Science*, Vol. 39, No. 5, pp. 667–694. https://doi.org/10.1007/s11251-010-9148-z

Bhardwaj, V., Zhang, S., Tan, Y. Q. and Pandey, V. (2025) 'Redefining learning: Student-centered strategies for academic and personal growth', *Frontiers in Education*, Vol. 10, p. 1518602. https://doi.org/10.3389/feduc.2025.1518602

Bicer, A., Marquez, A., Colindres, K. V. M., Schanke, A. A., Castellon, L. B., Audette, L. M., Perihan, C. and Lee, Y. (2021) 'Investigating creativity-directed tasks in middle school mathematics curricula', *Thinking Skills and Creativity*, Vol. 40, p. 100823. https://doi.org/10.1016/j.tsc.2021.100823

Çela, E., Fonkam, M. and Potluri, R. M. (2024) 'Risks of AI-Assisted Learning on Student Critical Thinking', *International Journal of Risk and Contingency Management*, Vol. 12, No. 1, pp. 1–19. https://doi.org/10.4018/ijrcm.350185

Chaleelpliam, S., Premthaisong, S. and Chaipidech, P. (2023) 'Implementing an inquiry learning with mobile-supported mathematical board game to promote primary students' attitude toward mathematics learning', in: *IEEE International Conference on Consumer Electronics (ICCE 2023)*. https://doi.org/10.58459/icce.2023.4758

Cirneanu, A.-L. and Moldoveanu, C.-E. (2024) 'Use of digital technology in integrated mathematics education', *Applied System Innovation*, Vol. 7, No. 4, p. 66. https://doi.org/10.3390/asi7040066

Conradty, C. and Bogner, F. X. (2019) 'From STEM to STEAM: Cracking the Code? How Creativity and Motivation Interacts with Inquiry-based Learning', *Creativity Research Journal*, Vol. 31, No. 3, pp. 284–295. https://doi.org/10.1080/10400419.2019.1641678

Dagys, D. (2017) 'Theoretical Inquiry-Based Learning Insights on Natural Science Education: From the Source to 5E Model', *Pedagogika*, Vol. 126, No. 2, pp. 83–98. https://doi.org/10.15823/p.2017.21

Dong, H., Chen, X. and Shen, J. (2026) 'Unpacking the impact mechanism of generative AI-based learning analytics technology on student learning engagement: The mediating role of community of inquiry and the moderating role of digital literacy', *International Journal of Educational Technology in Higher Education*, Vol. 23, No. 1, p. 14. https://doi.org/10.1186/s41239-026-00591-z

Engelbrecht, J. and Borba, M. C. (2024) 'Recent developments in using digital technology in mathematics education', *ZDM–Mathematics Education*, Vol. 56, No. 2, pp. 281–292. https://doi.org/10.1007/s11858-023-01530-2

Engeln, K., Euler, M. and Maass, K. (2013) 'Inquiry-based learning in mathematics and science: A comparative baseline study of teachers' beliefs and practices across 12 European countries', *ZDM - Mathematics Education*, Vol. 45, No. 6, pp. 823–836. https://doi.org/10.1007/s11858-013-0507-5

Guo, H., Zhou, Z. and Ma, F. (2025) 'The influence of artificial intelligence generated content-based problem-solving on engineering students' creativity: A controlled experimental study', *Education and Information Technologies*, Vol. 30, No. 18, pp. 1–31. https://doi.org/10.1007/s10639-025-13709-z

Haq, A. U. (2025) 'Innovating Education: The Impact of Artificial Intelligence and Technology on Teaching', *Inverge Journal of Social Sciences*, Vol. 4, No. 2, pp. 52–68. https://doi.org/10.63544/ijss.v4i2.125

Hidayatullah, A., Abidin, R. and Muqit, A. (2024) 'Motivation and behavioral engagement: The mediating role of mathematics self-efficacy in primary education', *Journal on Efficiency and Reponsibility in Education and Science*, Vol. 17, No. 3, pp. 237–246. https://doi.org/10.7160/eriesj.2024.170306

Hidayatullah, A. and Csíkos, C. (2023) 'Exploring Students' Mathematical Beliefs: Gender, Grade, and Culture Differences', *Journal on Efficiency and Responsibility in Education and Science*, Vol. 16, No. 3, pp. 186–195. https://doi.org/10.7160/eriesj.2023.160303

Hidayatullah, A. and Csíkos, C. (2025) 'Association between psychological need satisfaction and online self-regulated learning', *Asia Pacific Education Review*, Vol. 26, No. 3, pp. 609–619. https://doi.org/10.1007/s12564-023-09910-9

Huang, Y. (2022) 'Effectiveness of inquiry-based science laboratories for improving teamwork and problem-solving skills and attitudes', *Journal of Research in Science Teaching*, Vol. 59, No. 3, pp. 329–357. https://doi.org/10.1002/tea.21729

Hussain, I. (2020) 'Attitude of University Students and Teachers Towards Instructional Role of Artificial Intelligence', *International Journal of Distance Education and E-Learning*, Vol. 5, No. 2, pp. 158–177. https://doi.org/10.36261/ijdeel.v5i2.1057

Hwang, S. and Son, T. (2021) 'Students' Attitude toward Mathematics and Its Relationship with Mathematics Achievement', *Journal of Education and E-Learning Research*, Vol. 8, No. 3, pp. 272–280. https://doi.org/10.20448/journal.509.2021.83.272.280

Kadir, L., Lucyana, L. and Satriawati, G. (2016) 'The implementation of open-inquiry approach to improve students' learning activities, responses, and mathematical creative thinking skills', *Journal on Mathematics Education*, Vol. 8, No. 1, pp. 103–114. https://doi.org/10.22342/jme.8.1.3406.103-114

Kalyuga, S. and Singh, A.-M. (2016) 'Rethinking the boundaries of cognitive load theory in complex learning', *Educational Psychology Review*, Vol. *28*, No. 4, pp. 831–852. https://doi.org/10.1007/s10648-015-9352-0

Khan, M. A. and Begun, H. (2025) 'The Impact of AI-Supported Classroom Activities on Enhancing Critical Thinking and Problem-Solving Skills', *Research Journal for Social Affairs*, Vol. 3, No. 6, pp. 231–233. https://doi.org/10.71317/rjsa.003.06.0448

Kim, M., Jo, S. and Yoo, Y. (2025) 'Development and Effect Analysis of Augmented Reality Tools for Mathematical Modeling', *School Mathematics*, Vol. 27, No. 1, pp. 111–137. https://doi.org/10.57090/sm.2025.03.27.1.111

Kline, R. B. (2015) Principles and Practice of Structural Equation Modeling, 4th edn, New York: Guilford Press.

Kolbe, T., Steele, C. and White, B. (2020) 'Time to teach: Instructional time and science teachers' use of inquiry-oriented instructional practices', *Teachers College Record*, Vol. 122, No. 12, pp. 1–54. https://doi.org/10.1177/016146812012201211

Lai, C.-J. (2025) 'Evaluating generative AI-assisted inquiry-based learning and metacognitive scaffolding for enhancing scientific vocabulary, content comprehension, and lab report writing', *Interactive Learning Environments*, 1–15. https://doi.org/10.1080/10494820.2025.2572786

Lee, C., and So, H.-J. (2025) 'Learners leveraging generative AI for creative problem solving: Focusing on the PISA 2022 creative thinking problems', *Educational Technology and Society*, Vol. 28, No. 4, pp. 241–258. https://doi.org/10.30191/ETS.202510_28(4).SP04

Li, P.-H., Wu, T.-T. and Huang, Y.-M. (2025) 'Improving inquiry-based learning through automated ChatGPT-based inquiry prompt and behavioral image recognition', *Education and Information Technologies*, Vol. 30, No. 17, pp. 25543–25575. https://doi.org/10.1007/s10639-025-13734-y

Liu, B., Zhang, W. and Wang, F. (2026) 'Can Generative Artificial Intelligence Effectively Enhance Students' Mathematics Learning Outcomes?—A Meta-Analysis of Empirical Studies from 2023 to 2025', *Education Sciences*, Vol. 16, No. 1, p. 140. https://doi.org/10.3390/educsci16010140

Liu, J., Sun, D., Sun, J., Wang, J. and Yu, P. L. H. (2025) 'Designing a generative AI enabled learning environment for mathematics word problem solving in primary schools: Learning performance, attitudes and interaction', *Computers and Education: Artificial Intelligence*, Vol. 9, p. 100438. https://doi.org/10.1016/j.caeai.2025.100438

Niyonizera, D. and Faustin, M. (2023) 'Teaching and Learning Methods and Students Performance in Mathematics in Public Secondary Schools in Rwanda: A Case of Nyamasheke District', *Cognizance Journal of Multidisciplinary Studies*, Vol. 3, No. 10, pp. 216–239. https://doi.org/10.47760/cognizance.2023.v03i10.017

Opesemowo, O. A. G. and Ndlovu, M. (2024) 'Artificial Intelligence in Mathematics Education: The Good, the Bad, and the Ugly', *Journal of Pedagogical Research*., Vol. 8, No. 3, pp. 333–346. https://doi.org/10.33902/jpr.202426428

Orhani, S. (2021) 'Artificial Intelligence in Teaching and Learning Mathematics', *Kosova Eğitim Araştırmaları Dergisi*, Vol. 2/3, No. 2/3, pp. 29–38. https://doi.org/10.29228/kerjournal.54981

Piaget, J. (1976) 'Piaget's theory', in: Inhelder, B., Chipman, H. H. and Zwingmann, C. (eds.), *Piaget and His School*, Berlin: Springer, pp. 11–23. https://doi.org/10.1007/978-3-642-46323-5_2

OECD (2024) *PISA 2022 Results (Volume III): Creative Minds, Creative Schools*, Paris: OECD Publishing. https://doi.org/10.1787/765ee8c2-en

Sam, R. (2024) 'Systematic review of inquiry-based learning: Assessing impact and best practices in education', *F1000Research*, Vol. 13, p. 1045. https://doi.org/10.12688/f1000research.155367.1

Shakya, S. and Maharjan, R. (2023) 'Students' Attitude Towards Mathematics and Its Relationship With Mathematics Achievement', *Mangal Research Journal*, Vol. 4, No. 01, pp. 29–40. https://doi.org/10.3126/mrj.v4i01.61718

Sirnoorkar, A., Zollman, D., Laverty, J. T., Magana, A. J., Rebello, N. S. and Bryan, L. A. (2024) 'Student and AI responses to physics problems examined through the lenses of sensemaking and mechanistic reasoning', *Computers and Education: Artificial Intelligence*, Vol. 7, p. 100318. https://doi.org/10.1016/j.caeai.2024.100318

Smith, K., Maynard, N., Berry, A., Stephenson, T., Spiteri, T., Corrigan, D., Mansfield, J., Ellerton, P. and Smith, T. (2022) 'Principles of problem-based learning (PBL) in STEM education: Using expert wisdom and research to frame educational practice', *Education Sciences,* Vol. 12, No. 10, p. 728. https://doi.org/10.3390/educsci12100728

Strielkowski, W., Grebennikova, V., Lisovskiy, A., Rakhimova, G. and Vasileva, T. (2025) 'AI-driven adaptive learning for sustainable educational transformation', *Sustainable Development*, Vol. 33, No. 2, pp. 1921–1947. https://doi.org/10.1002/sd.3221

Suherman, S. and Vidákovich, T. (2022) 'Adaptation and validation of students' attitudes toward mathematics to Indonesia', *Pedagogika*, Vol. 147, No. 3, pp. 227–252. https://doi.org/10.15823/p.2022.147.11

Suherman, S. and Vidákovich, T. (2024) 'Mathematical creative thinking-ethnomathematics based test: Role of attitude toward mathematics, creative style, ethnic identity, and parents' educational level', *Revista de Educación a Distancia (RED)*, Vol. 24, No. 77, p. 1. https://doi.org/10.6018/red.581221

Suherman, S. and Vidákovich, T. (2025) 'Ethnomathematical test for mathematical creative thinking', *Journal of Creativity*, Vol. 35, No. 2, p. 100099. https://doi.org/10.1016/j.yjoc.2025.100099

Suherman, S., Vidákovich, T., Mujib, M., Hidayatulloh, H., Andari, T. and Susanti, V. D. (2025) 'The role of STEM teaching in education: An empirical study to enhance creativity and computational thinking', *Journal of Intelligence*, Vol. 13, No. 7, p. 88. https://doi.org/10.3390/jintelligence13070088

Supriadi, N., Jamaluddin, W., Suherman, S. and Komarudin, K. (2025) 'The Role of Blended Learning in Improving Students' Numerical Ability and Learning Creativity', *Revista de Educación a Distancia (RED)*, Vol. 25, No. 81, P. 4. https://doi.org/10.6018/red.619061

Syahgiah, L., Zan, A. M. and Asrizal, A. (2023) 'Effects of Inquiry Learning on Students' Science Process Skills and Critical Thinking: A Meta-Analysis', *Journal of Innovative Physics Teaching*, Vol. 1, No. 1, pp. 16–28. https://doi.org/10.24036/jipt/vol1-iss1/9

Thoron, A. C. and Burleson, S. E. (2014) 'Students' Perceptions of Agriscience When Taught Through Inquiry-Based Instruction', *Journal of Agricultural Education*, Vol. 55, No. 1, pp. 66–75. https://doi.org/10.5032/jae.2014.01066

Umbara, T., Fananta, M. R. and Hastuti, S. D. (2017) 'Design development of inquiry-based teacher training to support primary teacher's pedagogical content knowledge', *Advances in Social Science, Education and Humanities Research*, Vol. 57, pp. 189–194. https://doi.org/10.2991/icmsed-16.2017.41

Wale, B. D. and Bishaw, K. S. (2020) 'Effects of Using Inquiry-Based Learning on EFL Students' Critical Thinking Skills', *Asian-Pacific Journal of Second and Foreign Language Education*, Vol. 5, No. 1., p. 9. https://doi.org/10.1186/s40862-020-00090-2

Wang, X. and Wei, Y. (2025) 'The Influence of Gen-AI Assisted Learning on Primary School Students' Math Anxiety: An Intervention Study', *Applied Cognitive Psychology*, Vol. 39, No. 4. https://doi.org/10.1002/acp.70088

Wei, X., Wang, L., Lee, L.-K. and Liu, R. (2025) 'The effects of generative AI on collaborative problem-solving and team creativity performance in digital story creation: An experimental study', *International Journal of Educational Technology in Higher Education*, Vol. 22, No. 1, p. 23. https://doi.org/10.1186/s41239-025-00526-0

Yeh, H.-C. (2025) 'The synergy of generative AI and inquiry-based learning: Transforming the landscape of English teaching and learning', *Interactive Learning Environments*, Vol. 33, No. 1, pp. 88–102. https://doi.org/10.1080/10494820.2024.2335491

Zhai, C., Wibowo, S. and Li, L. D. (2024) 'The effects of over-reliance on AI dialogue systems on students' cognitive abilities: A systematic review', *Smart Learning Environments*, Vol. 11, No. 1, p. 28. https://doi.org/10.1186/s40561-024-00316-7