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Artificial intelligence-assisted project-based learning: Examining the interaction with learning creativity on the students' digital content outcomes

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ABSTRACT

Despite the rapid integration of artificial intelligence (AI) in education, limited empirical evidence compares the effectiveness of AI-assisted project-based learning (PjBL) and problem-based learning (PBL) while considering students' learning creativity in digital content production. This study aims to examine the effects of AI-assisted PjBL and AI-assisted PBL, as well as their interaction with students' learning creativity, on learning outcomes in digital content production. The study employs a 2×2 quasi-experimental factorial design, in which factor (A) represents the learning model (AI-assisted PjBL and AI-assisted PBL) and factor (B) represents learning creativity (high and low). The population consists of eighth-grade students at the junior high school level. The findings address four hypotheses: (1) there is a significant difference in learning outcomes between students receiving AI-assisted PjBL and those receiving AI-assisted PBL (Sig. 0.043 < 0.05); (2) there is a significant interaction effect between AI-assisted learning models and learning creativity (Sig. 0.000 < 0.05); (3) students with high creativity who receive AI-assisted PjBL achieve higher learning outcomes than those receiving AI-assisted PBL (Sig. 0.000 < 0.05); and (4) students with low creativity who receive AI-assisted PjBL demonstrate lower learning outcomes than those receiving AI-assisted PBL (Sig. 0.000 < 0.05). These findings indicate that AI-assisted PjBL and learning creativity enhance students' learning outcomes in producing creative digital content, particularly for students with high learning creativity. This study contributes empirical evidence to the integration of AI in junior high school computer science education.

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Introduction

The implementation of education in Indonesia is guided by three interrelated standards: process, assessment, and management. In the process standards regulated in Permendikbudristek Number 53 of 2023 concerning Quality Assurance (Permendikbudristek, 2024), Articles 12, 13, and 14 emphasize the selection of

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appropriate learning models, the effective use of learning resources, and the creation of meaningful learning environments aligned with instructional objectives. In this context, artificial intelligence (AI) emerges as a transformative innovation in education. Che Ghazali et al. (2025) argue that AI has strong potential to personalize instruction, provide learning analytics, and support data-driven decision-making for educators. Likewise, Wang and Huang et al. (2025) demonstrate that AI-enhanced environments foster engagement, conceptual understanding, and problem-solving skills across contexts. However, they emphasize that AI must be pedagogically integrated and ethically implemented, reinforcing its role as a human-centered instructional support rather than a replacement for teachers.

The quality of the learning process is reflected not only in classroom assessment results but also in broader institutional indicators such as the education report card. Initial observations based on documentation from Kurnia Junior High School show that the quality of learning decreases by 0.88 points in 2024, with the learning model component scoring only 56/100. The implementation of innovative practices through teacher reflection and instructional improvement also remains low at 58.12/100. According to Dikdasmen (2025), such conditions are closely related to limited pedagogical and professional competence among teachers. These findings highlight an urgent need to strengthen instructional strategies that are innovative, technology-integrated, and responsive to learners' needs. Without systematic improvement in learning models, efforts to enhance student achievement and institutional learning quality may not produce sustainable progress.

Further document analysis conducted with informatics teachers reveals a decline in student achievement in digital content production, with 54.30% of students failing to meet the minimum competency criteria compared to the previous year. Digital content production requires high levels of learning creativity, as students must actively engage in planning, designing, implementing, and evaluating creative products. To assess students' creativity, a questionnaire based on indicators proposed by Munandar (2022) is administered, including curiosity, originality, imagination, flexibility, and problem-solving ability. The results indicate considerable room for improvement in students' confidence and active participation. Roll and Wylie (2021) explain that AI in education supports adaptive learning and metacognitive scaffolding when aligned with sound pedagogical design. These findings suggest that integrating AI-assisted interactive learning models may stimulate creativity while improving engagement and learning outcomes.

Project-based learning (PjBL) and problem-based learning (PBL) are widely recognized as student-centered approaches that promote higher-order thinking and authentic problem solving. Ruiz Viruel et al. (2025) report that AI integration in PjBL strengthens inquiry processes and collaborative engagement. Kokotsaki et al. (2020) and Guo et al. (2020) conclude that PjBL enhances deep learning, motivation, and academic achievement when supported by appropriate scaffolding and assessment design. Meanwhile, Dolmans et al. (2021) emphasize that PBL develops critical thinking and self-directed learning, particularly when adapted to technology-enhanced environments. Svabo et al. (2025) conceptualize creativity as a dynamic process shaped by instructional design, while Rafiq-uz-Zaman (2025) defines creativity as the production of ideas that are both novel and useful. Sun and Zhou (2024) further demonstrate that technology-supported instruction fosters creativity and positively influences academic performance.

In a thematic analysis, empirical evidence across educational contexts indicates several consistent themes regarding AI-supported PjBL and PBL. First, technology-enhanced project- and problem-based approaches tend to improve cognitive engagement, collaborative problem solving, and conceptual understanding when instructional scaffolding is intentionally designed (Cheruiyot & Molnár, 2025; Hikmah et al., 2025; Mota et al., 2025). Studies frequently report gains in academic achievement, motivation, and task persistence, particularly when learners are required to produce authentic outputs or solve real-world problems (Asad & Qureshi, 2025; Yiling et al., 2025; Zhou et al., 2025).

Second, the integration of intelligent systems, such as adaptive feedback tools and learning analytics, appears to strengthen metacognitive regulation and iterative refinement processes, which are essential in creative and product-oriented tasks (Drigas et al., 2023; Sun, 2025). Third, learner characteristics, including prior knowledge, digital literacy, and creative disposition, moderate the effectiveness of these approaches (Nopas, 2025; Thiangtham et al., 2026). While highly autonomous and creative learners benefit from open-ended, exploratory environments, students with lower readiness often require structured guidance. However, most empirical studies examine either instructional models or learner variables separately, leaving limited evidence on how AI-assisted PjBL and PBL interact with individual creativity levels within a unified experimental framework.

Although prior studies examine PjBL, PBL, and AI integration, most investigate these variables independently and primarily at the higher education level. Empirical comparisons between AI-assisted PjBL and AI-assisted PBL within a single experimental framework remain limited, particularly in junior high school contexts. Moreover, learning creativity is rarely positioned as a moderating variable that interacts with AI-assisted pedagogical approaches to influence learning outcomes. This gap is especially critical in digital content production, where creativity directly determines product quality and originality. Without examining the interaction between AI-assisted learning models and varying levels of creativity, the effectiveness of AI integration may be only partially understood. Therefore, systematic empirical investigation is required to clarify how different AI-assisted learning models interact with students' creativity in shaping learning outcomes.

This study aims to investigate the comparative and interaction effects of artificial intelligence–assisted project-based learning and problem-based learning on students' digital content production outcomes, considering learning creativity as a moderating variable. Situated within the design and utilization domain of educational technology, this research develops and implements AI-assisted PjBL and AI-assisted PBL strategies in eighth-grade informatics classes. Both groups utilize AI tools to support inquiry processes, feedback mechanisms, and content development activities. Specifically, the study examines: (1) the direct effect of AI-assisted learning models on learning outcomes; (2) the interaction effect between AI-assisted learning models and learning creativity; and (3) the differential effects of AI-assisted models on students with high and low creativity levels. By addressing these objectives, the study provides novel empirical evidence regarding the moderating role of creativity in AI-supported pedagogy and strengthens instructional design practices in junior high school informatics education.

Method

This study employs an experimental method with a quantitative approach, which is considered one of the most rigorous designs for examining causal relationships between variables (Arief, 2014; Phakiti, 2015). Experimental research is specifically intended to test the effect of an independent variable on a dependent variable under controlled conditions, allowing researchers to determine whether observed differences are attributable to the treatment rather than external factors. In this study, the independent variable is the type of AI-assisted learning model, while the dependent variable is students' learning outcomes in digital content production, with learning creativity treated as a moderating variable. A factorial experimental design is selected because it enables the simultaneous examination of main effects and interaction effects between variables. This design is particularly suitable for identifying whether the effectiveness of AI-assisted instructional models varies according to students' levels of creativity. To provide a clearer description of the intervention procedures, Table 1 presents the structured teaching–learning activities implemented during the experimental phase.

Table 1. Teaching–learning activities during experimental implementation

Phase	**Teaching-learning Activities**	**Learning Materials**	**Learning Strategies**	**Role of Artificial Intelligence**
Preliminary Phase	Teacher explains learning objectives, assessment criteria, and introduces digital content production topics. Students complete a learning creativity questionnaire and pre-orientation tasks.	Syllabus, lesson plan, creativity questionnaire, introductory digital content examples	Orientation, motivation, diagnostic assessment	AI used to provide initial explanations, examples of digital content, and clarify concepts through interactive prompts
Problem/Project Orientation	Students are presented with real-world problems or project themes related to digital content production.	Problem scenarios, project briefs, digital content cases	Contextual learning, inquiry-based orientation	AI assists in generating problem scenarios, project ideas, and guiding questions
Planning Phase	Students plan solutions/projects, determine tools, content concepts, and workflows individually or in groups.	Project worksheets, planning templates	Project-based planning (PjBL) / Problem analysis (PBL)	AI supports brainstorming, content outlining, idea refinement, and feasibility checking
Investigation / Development Phase	Students collect information, design, and produce digital content (e.g., videos, posters, interactive media).	Digital production tools, learning modules	Collaborative learning, experimentation, hands-on practice	AI provides technical guidance, content suggestions, feedback, and creative enhancement ideas
Implementation Phase	Students execute projects or problem solutions based on plans and revise outputs.	Digital content drafts, editing tools	Active learning, iterative development	AI offers real-time feedback, optimization suggestions, and error detection
Presentation Phase	Students present final digital content products and explain the process and outcomes.	Final digital products, presentation media	Presentation, communication, peer learning	AI supports presentation structure, visualization, and clarity of explanation
Evaluation and Reflection Phase	Teacher and students conduct reflection, assessment, and feedback on learning outcomes and creativity.	Assessment rubrics, reflection sheets, portfolios	Reflective learning, formative and summative assessment	AI assists in self-reflection prompts, rubric-based feedback, and learning summaries

This study employs a 2×2 factorial research design to examine the effects of two independent variables simultaneously and to identify their interaction effect on students' learning outcomes. The first factor (A) is the AI-assisted learning model, consisting of AI-assisted Project-Based Learning (PjBL) and AI-assisted Problem-Based Learning (PBL). The second factor (B) is students' learning creativity, categorized into high and low levels based on the creativity assessment results. Through this design, the study not only analyzes the main effect of each learning model and creativity level on digital content production outcomes but also investigates whether the effectiveness of each AI-assisted model differs depending on students' creativity levels. This factorial approach is particularly appropriate because it allows for a more comprehensive understanding of how instructional strategies and learner characteristics interact in shaping achievement. Table 2 presents the structure and explanation of the 2×2 factorial design applied in this research.

Table 2. Factorial Design 2x2

Treatment (A) / **Attribute (B)**	**AI-Assisted Learning Project (A1)**	**AI-Assisted Problem Based Learning (A2)**
High Creativity (B1)	A1 B1	A2 B1
Low Creativity (B2)	A1 B2	A2 B2

The population of this study consists of 150 eighth-grade students enrolled in junior high school. From this population, two intact classes are selected to serve as the experimental and control groups, each consisting of 32 students. To examine the moderating role of learning creativity, students are categorized into high and low creativity groups using the extreme group method with a 27% proportion. This procedure is commonly used to obtain clear distinctions between upper and lower groups for comparative analysis. Based on this classification, eight students with high learning creativity and eight students with low learning creativity are identified in each class. Consequently, the factorial analysis involves 32 focal participants, comprising 16 students from the experimental class and 16 students from the control class, representing combinations of learning model and creativity level. This sampling structure ensures balanced group representation and strengthens the internal validity of the factorial 2×2 experimental design.

Data collection in this study employs multiple techniques to ensure comprehensive and valid data acquisition. First, structured interviews are conducted between the researcher and the informatics teacher to obtain contextual information regarding instructional practices and student performance. The interviews follow a guideline consisting of key questions aligned with the research objectives. Second, field observations are carried out during the learning process to document instructional activities and student engagement using systematic recording procedures (Kurniawan, 2018). Third, a learning creativity questionnaire is administered to categorize students into high and low creativity groups. The questionnaire consists of written statements that respondents answer based on their learning behaviors. Finally, students' learning outcomes are assessed using a portfolio-based performance evaluation, as digital content production requires authentic assessment of students' creative products rather than traditional written tests.

Data analysis is conducted in two stages: descriptive and inferential statistical analysis. Descriptive analysis aims to summarize and present the data through measures of central tendency and dispersion, including mean scores and standard deviations, as well as frequency distribution tables and histograms. This stage provides an overview of students' learning outcomes across treatment groups without making broader generalizations. Inferential analysis is then performed to test the research hypotheses. Prior to hypothesis testing, prerequisite tests are conducted, including normality and homogeneity tests, to ensure that the data meet statistical assumptions. Hypothesis testing is carried out using two-way ANOVA (ANAVA 2×2) to examine both main and interaction effects between AI-assisted learning models and learning creativity. When significant differences are identified, a Tukey post hoc test is applied to determine specific group differences. Inferential analysis ultimately enables the formulation of statistically supported research conclusions.

Results

The results of this study are presented to address the research objectives and to test the proposed hypotheses concerning the effects of artificial intelligence (AI)–assisted learning models and learning creativity on students' digital content production outcomes. Specifically, this study examines whether there is a significant difference in learning outcomes between students who are taught using AI-assisted project-based learning (PjBL) and those who are taught using AI-assisted problem-based learning (PBL) (H_0: μA1 = μA2). In addition, the analysis investigates whether there is an interaction effect between the AI-assisted learning model and students' learning creativity on learning outcomes (H_0: Int A × B = 0). The study further tests whether students with high learning creativity who are taught using AI-assisted PjBL achieve higher outcomes than those taught using AI-assisted PBL (H_0: μA1B1 = μA2B1). Finally, it examines whether students with low learning creativity who are taught using AI-assisted PjBL demonstrate lower outcomes than those taught using AI-assisted PBL (H_0: μA1B2 = μA2B2). These analyses provide a comprehensive understanding of both main and interaction effects within the factorial design.

Data description

The data presented in this section describe students' learning outcomes in digital content production across the treatment and creativity groups. Specifically, the dataset includes: A1 (learning outcomes of students taught using AI-assisted Project-Based Learning), A2 (learning outcomes of students taught using AI-assisted Problem-Based Learning), A1B1 (learning outcomes of students with high learning creativity taught using AI-assisted Project-Based Learning), A1B2 (learning outcomes of students with low learning creativity taught using AI-assisted Project-Based Learning), A2B1 (learning outcomes of students with high learning creativity taught using AI-assisted Problem-Based Learning), and A2B2 (learning outcomes of students with low learning creativity taught using AI-assisted Problem-Based Learning). These groupings align with the 2×2 factorial design and allow for examination of both main and interaction effects. A comprehensive summary of the descriptive statistical results is presented in Table 3.

Based on Table 3 in the high learning creativity group (B1), students taught using AI-assisted PjBL (A1B1) obtain a mean score of 34.13, with a median of 34, a minimum score of 33, and a maximum score of 35. The standard deviation is 0.83, indicating relatively homogeneous performance. In contrast, students with high creativity taught using AI-assisted PBL (A2B1) achieve a lower mean score of 29.50, with a median of 29.50, a minimum of 29, a maximum of 30, and a standard deviation of 0.53. In the low learning creativity group (B2), students taught using AI-assisted PjBL (A1B2) obtain a mean score of 30.88, with a median of 30.50, a minimum of 30, a maximum of 33, and a standard deviation of 1.13. Meanwhile, students with low creativity taught using AI-assisted PBL (A2B2) achieve a slightly higher mean score of 31.38, with a median of 31.50, a minimum of 30, a maximum of 33, and a standard deviation of 1.06. When viewed from the overall treatment perspective, the AI-assisted PjBL group (A1) with 16 students records an overall mean of 31.81, a median of 31.50, a minimum score of 29, and a maximum of 35, with a standard deviation of 2.48. The AI-assisted PBL group (A2), also consisting of 16 students, shows an overall mean of 31.13, a median of 31, a minimum of 30, and a maximum of 33, with a standard deviation of 1.09. These descriptive findings indicate a tendency for AI-assisted PjBL to produce higher outcomes among students with high creativity, while AI-assisted PBL shows slightly better performance among students with low creativity, suggesting a potential interaction effect to be further examined through inferential analysis.

Table 3. Results of descriptive analysis

Attribute (B)	**Statistical Data**	**Treatment (A)**	
		Learning Outcomes *AI-Assisted PjBL* (A1)	**Learning Outcomes *AI-Assisted PBL* (A2)**
Higher Learning Creativity (B1)	N	8	8
	Average *Y*	34.13	29.50
	Median	34	29.50
	Minimum	33	29
	Maximum	35	30
	Baku Junction	0.83	0.53
Low Learning Creativity (B2)	N	8	8
	Average *Y*	30.88	31.38
	Median	30.50	31.50
	Minimum	30	30
	Maximum	33	33
	Baku Junction	1.13	1.06
N		16	16
Average *Y*		31.81	31.13
Median		31.50	31
Minimum		29	30
Maximum		35	33
Baku Junction		2.48	1.09

(Source: SPSS Calculation Results, 2025)

Results of prerequisite tests

The first prerequisite analysis conducted in this study is the normality test, which aims to determine whether the data distribution in each group meets the assumption of normality prior to inferential statistical testing. The results of the normality test presented in Table 4 indicate that the distribution of data in all observed groups satisfies the assumption of normality. The test was conducted using the Liliefors normality test with a significance level of $\alpha = 0.05$. Based on the decision rule, the null hypothesis (H_0), which states that the data are normally distributed, is accepted when the obtained p-value is greater than 0.05. Conversely, if the p-value is less than 0.05, the null hypothesis is rejected, indicating that the data do not follow a normal distribution. As shown in Table 4, the p-values for the main groups A1, A2, B1, and B2 are all above the threshold value of 0.05. Specifically, groups A1, A2, and B1 each obtained a p-value of 0.200, while group B2 produced a p-value of 0.160. These results indicate that the learning outcome data in each primary treatment group are normally distributed. Furthermore, the normality test was also conducted for the four factorial interaction groups: A1B1, A1B2, A2B1, and A2B2. The results reveal p-values of 0.200, 0.174, 0.200, and 0.200 respectively, all of which exceed the significance level of 0.05. Since every group shows a p-value greater than the critical value, the null hypothesis of normal distribution is accepted for all datasets. This confirms that the learning outcome scores across different instructional strategies and creativity levels follow a normal distribution. Therefore, the data meet the statistical assumption required for applying further parametric analyses, such as factorial analysis of variance (ANOVA), in the subsequent stages of the study.

Table 4. Normality test results of learning outcomes in digital content production

No.	Group	N	p-value	Conclusion
1.	A1	16	.200	Normally Distributed
2.	A2	16	.200	Normally Distributed
3.	B1	16	.200	Normally Distributed
4.	B2	16	.160	Normally Distributed
5.	A1B1	8	.200	Normally Distributed
6.	A1B2	8	.174	Normally Distributed
7.	A2B1	8	.200	Normally Distributed
8.	A2B2	8	.200	Normally Distributed

(Source: SPSS Calculation Results, 2025)

Following the confirmation of normality, a homogeneity of variance test is conducted to determine whether the variances among comparison groups are equal. Homogeneity is a crucial assumption for two-way ANOVA, as unequal variances may bias the interpretation of main and interaction effects. The test compares three sets of groupings: (1) students taught using AI-assisted Project-Based Learning (A1) and AI-assisted Problem-Based Learning (A2); (2) students with high learning creativity (B1) and low learning creativity (B2); and (3) the four combined factorial groups (A1B1, A1B2, A2B1, A2B2) using Levene's test. As shown in Table 5, the comparison between A1 and A2 yields a p-value of 0.055 (> 0.05), indicating homogeneous variances. The comparison between B1 and B2 results in a p-value of 0.493 (> 0.05), also confirming homogeneity. Furthermore, Levene's test for the four cells produces a p-value of 0.410 (> 0.05), demonstrating that all groups have equal variances. These results indicate that the assumption of homogeneity is satisfied, thereby validating the use of two-way ANOVA for hypothesis testing.

Table 5. Results of homogeneity test for digital content production

No.	Group	p-value	Conclusion
1.	A1 and A2	0.055	Homogeneous
2.	B1 and B2	0.493	Homogeneous
3.	Four cells	0.410	Homogeneous

(Source: SPSS Calculation Results, 2025)

Hypothesis testing results

Two-way ANOVA in this study is to examine the main effects of AI-assisted learning models and learning creativity, as well as their interaction effect on students' digital content production outcomes. As shown in Table 6, the corrected model is statistically significant (F = 35.891, Sig. = 0.000), indicating that the combination of variables explains a substantial proportion of variance in learning outcomes. The main effect of the AI-assisted learning model is significant (F = 4.481, Sig. = 0.043 < 0.05), demonstrating a difference between AI-assisted PjBL and AI-assisted PBL. Learning creativity also shows a significant main effect (F = 40.333, Sig. = 0.000), confirming that students with different creativity levels achieve significantly different outcomes. Importantly, the interaction between AI-assisted learning models and learning creativity is highly significant (F = 62.259, Sig. = 0.000), indicating that the effectiveness of the learning model depends on students' creativity levels. This finding supports the presence of a moderating effect within the factorial design.

Table 6. Tests of between-subjects effects (two-way ANOVA)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	90.347[a]	3	30.115	35.891	.000
Intercept	3159.003	1	3159.003	3755.37	.000
AI-Assisted Learning Model	3.781	1	3.781	4.481	.043
Learning Creativity	34.031	1	34.031	40.333	.000
AI-Assisted Learning Model × Learning Creativity	52.531	1	52.531	62.259	.000
Error	23.625	28	0.844	—	—
Total	3153.000	32	—	—	—
Corrected Total	113.969	31	—	—	—

(Source: SPSS Calculation Results, 2025)

The function of the interaction analysis presented in Table 7 is to clarify how the mean learning outcomes differ across combinations of learning models and creativity levels. The table shows that students with high creativity achieve the highest mean score when taught using AI-assisted PjBL (34.13), compared to AI-assisted PBL (30.88). Conversely, among students with low creativity, AI-assisted PBL results in a higher mean score (31.38) than AI-assisted PjBL (29.50). These contrasting patterns indicate a crossover interaction, where the effectiveness of the instructional model varies according to creativity level. Specifically, AI-assisted PjBL appears more beneficial for students with high creativity, while AI-assisted PBL is relatively more effective for students with low creativity. This interaction pattern provides descriptive confirmation of the significant interaction effect identified in the two-way ANOVA and reinforces the importance of aligning instructional strategies with learner characteristics.

Table 7. Interaction between AI-assisted learning models and learning creativity

AI-Assisted Learning Model	High Learning Creativity	Low Learning Creativity
AI-Assisted Project-Based Learning	34.13	29.50
AI-Assisted Problem-Based Learning	30.88	31.38

The Tukey HSD post hoc test functions to identify specific group differences after a significant interaction effect is detected in the ANOVA. As shown in Table 8, several pairwise comparisons reveal statistically significant differences at the 0.05 level. The A1B1 group (AI-assisted PjBL with high creativity) differs significantly from A1B2, A2B1, and A2B2 (Sig. = 0.000), indicating that students with high creativity under AI-assisted PjBL outperform the other groups. Meanwhile, comparisons between A1B2 and A2B1 (Sig. = 0.771) and between A2B1 and A2B2 (Sig. = 0.570) are not statistically significant, suggesting comparable performance levels among those groups. These findings confirm that the highest performance is achieved by students with high creativity exposed to AI-assisted PjBL. The Tukey analysis therefore provides detailed evidence supporting the interaction effect and clarifies which specific group differences contribute to the overall significance.

Table 8. Multiple comparisons of learning outcomes using Tukey HSD test

(I) Group	(J) Group	Mean Difference (I–J)	Std. Error	Sig.	95% Confidence Interval (Lower Bound)	95% Confidence Interval (Upper Bound)
A1B1	A1B2	3.63*	0.39	0.000	2.38	4.87
A1B1	A2B1	3.25*	0.39	0.000	2.01	4.50
A1B1	A2B2	2.75*	0.39	0.000	1.50	4.00
A1B2	A1B1	-3.63*	0.39	0.000	-4.87	-2.38
A1B2	A2B1	-0.38	0.39	0.771	-1.63	0.87
A1B2	A2B2	-0.88	0.39	0.050	-2.13	0.38
A2B1	A1B1	-3.25*	0.39	0.000	-4.50	-2.01
A2B1	A1B2	0.38	0.39	0.771	-0.87	1.63
A2B1	A2B2	-0.50	0.39	0.570	-1.75	0.75
A2B2	A1B1	-2.75*	0.39	0.000	-4.00	-1.50
A2B2	A1B2	0.88	0.39	0.050	-0.38	2.13
A2B2	A2B1	0.50	0.39	0.570	-0.75	1.75

(Source: SPSS Calculation Results, 2025)
Notes: The mean difference is significant at the 0.05 level; A1B1 = AI-assisted PjBL with high creativity; A1B2 = AI-assisted PjBL with low creativity; A2B1 = AI-assisted PBL with high creativity; A2B2 = AI-assisted PBL with low creativity

Discussion

The findings demonstrate that AI-assisted Project-Based Learning (PjBL) exerts a more substantial influence on students' digital content production outcomes than AI-assisted Problem-Based Learning (PBL). Students exposed to AI-assisted PjBL achieve higher overall performance, indicating that structured project development supported by intelligent tools enhances product quality and conceptual understanding. These results are consistent with Habibah et al. (2025) and Simangunsong et al. (2023), who report that AI-integrated PjBL increases student participation, creativity, and knowledge achievement. Similarly, Saputra et al. (2024) find that AI-assisted PjBL produces more diverse and innovative learning products. The integration of artificial intelligence enables adaptive feedback, scaffolding, and real-time guidance, which are particularly valuable in project-oriented environments (Idawati & Neyarasmi, 2025; Wan, 2025). In the context of informatics education, where students are required to design and produce digital artifacts, AI-assisted PjBL aligns closely with practical competencies and authentic assessment demands. However, the superiority of this model should be interpreted within contextual boundaries, as instructional effectiveness may vary depending on learner characteristics.

The results further reveal a significant interaction between AI-assisted learning models and learning creativity, indicating that the effectiveness of instructional strategies depends on students' creativity levels. This finding supports Usmeldi (2019), who demonstrates that the impact of learning models on competence is moderated by students' creative capacity. In this study, AI functions not merely as a technological tool but as a pedagogical enhancer that amplifies students' creative engagement when aligned with appropriate instructional design. Well-structured AI-assisted PjBL activities provide opportunities for idea generation, experimentation, and iterative refinement, thereby fostering higher-order thinking (Harahap et al., 2025; Yu et al., 2023). Nevertheless, the presence of an interaction effect also suggests that AI integration alone is insufficient; teachers must intentionally design tasks that stimulate curiosity, flexibility, and originality. Without pedagogical alignment, AI risks becoming a technical supplement rather than a catalyst for meaningful learning. Therefore, instructional design and learner characteristics must be considered simultaneously.

For students with high learning creativity, AI-assisted PjBL yields significantly higher outcomes compared to AI-assisted PBL. Highly creative students appear to benefit from the autonomy, exploration, and product-oriented structure embedded in project-based environments. This finding reinforces Simangunsong et al. (2023) and Tendri and Ulli (2025), who highlight that AI-supported projects optimize student engagement and creative performance. Students with strong imaginative and problem-solving tendencies are better able to leverage AI tools for idea expansion, content refinement, and innovation. The combination of high creativity and AI-assisted PjBL creates a synergistic effect, enabling learners to translate abstract concepts into tangible digital products effectively (Dinu, 2025; Priyambudi et al., 2025). Critically, this suggests that AI does not replace creative thinking but enhances it when students possess sufficient creative readiness. Thus, differentiated instructional strategies are essential, as uniform implementation of AI-assisted models may not produce equivalent benefits across diverse learner profiles.

Conversely, among students with low learning creativity, AI-assisted PBL results in relatively higher outcomes than AI-assisted PjBL. This pattern may indicate that students with limited creative confidence require more structured problem-solving guidance rather than open-ended project demands. Fitria et al. (2024) caution that excessive reliance on artificial intelligence can potentially diminish independent critical and creative thinking if not carefully managed. In project-based contexts, students with low creativity may depend excessively on AI-generated suggestions, limiting genuine idea development. In contrast, problem-based learning offers clearer procedural steps and focused analytical tasks, which may better support learners who require cognitive scaffolding (Abidin et al., 2025; Ayanwale & Omeh, 2026). These findings highlight the importance of balancing technological assistance with teacher facilitation. AI should function as a supportive instrument within a thoughtfully designed pedagogical framework, ensuring that students gradually develop autonomy and creative competence rather than becoming dependent on automated solutions.

Theoretically, this study contributes to educational technology literature by empirically demonstrating the moderating role of learning creativity in AI-assisted instructional models. It extends prior research by integrating learner characteristics into the evaluation of AI-supported pedagogy within a factorial experimental design. Practically, the findings provide guidance for educators in selecting AI-assisted strategies that align with students' creativity profiles, particularly in digital content production contexts. Schools implementing AI technologies should emphasize pedagogical design, creativity development, and teacher training to maximize instructional impact. By highlighting the conditional effectiveness of AI-assisted learning models, this study advances evidence-based integration of artificial intelligence in junior high school informatics education.

Conclusion

This study confirms that artificial intelligence–assisted Project-Based Learning (PjBL) is more effective than artificial intelligence–assisted Problem-Based Learning (PBL) in enhancing students' learning outcomes in digital content production, particularly among students with high levels of learning creativity. A significant interaction effect between AI-assisted learning models and learning creativity indicates that the effectiveness of AI integration is conditional rather than universal. In other words, instructional impact depends on how well the learning model aligns with learners' creative characteristics. These findings emphasize that AI should be pedagogically embedded within appropriate instructional strategies rather than implemented as a stand-alone technological innovation. In informatics education, especially in product-oriented contexts such as digital content production, AI-assisted PjBL provides structured opportunities for exploration, design, and iterative refinement. Consequently, this study highlights the strategic importance of matching AI-supported instructional models with learner profiles to optimize engagement, creativity, and academic achievement.

Despite its contributions, this study has several limitations. The sample size is relatively small and drawn from a single junior high school, which may limit the generalizability of the findings to broader educational contexts. Additionally, the implementation of artificial intelligence depends on teachers' technological competence and the limited range of AI tools utilized during the intervention. Variations in teacher expertise or access to more advanced AI systems may produce different outcomes. Future research should involve larger and more diverse samples across multiple educational levels and subject domains to enhance external validity. Further studies may also examine additional moderating variables, such as digital literacy, learning motivation, self-regulated learning, or prior technological experience. Longitudinal investigations are recommended to explore the sustained impact of AI-assisted instructional models and to develop comprehensive pedagogical frameworks that ensure balanced, ethical, and effective integration of artificial intelligence in education.

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