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Development Of An AI-Assisted Inquiry Discovery Learning Model To Enhance Critical Thinking And Creativity Among Senior High School Students In South Sulawesi

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Abstract

This study aimed to develop and validate an AI-Assisted Inquiry Discovery Learning (AI-IDL) model and examine changes in students' critical thinking and creativity following its implementation in senior high school education. Using a Research and Development (R&D) approach, the study comprised needs analysis, model development, expert validation, revision, and implementation. The needs analysis involved 240 students and 12 teachers, while three experts evaluated the developed model. Content validity was assessed using Aiken's V, and implementation outcomes were examined using a one-group pretest–posttest design. The model achieved a mean Aiken's V coefficient of 0.924, with values ranging from 0.833 to 1.000, indicating high content validity. Following implementation, the mean critical-thinking score increased from 62.1542 to 79.1625, while the mean creativity score increased from 60.2042 to 75.3625. Both pretest–posttest differences were statistically significant ($p < .001$). The normalized gain values were 0.4690 for critical thinking and 0.3978 for creativity, both indicating moderate improvement. These findings provide initial empirical support for AI-IDL as an instructional model that integrates constructivism, inquiry, discovery, and artificial intelligence as learning support. The model emphasizes students' active roles in investigating problems, evaluating information,

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constructing knowledge, and developing ideas. However, the absence of a control group limits causal conclusions regarding the observed improvements.

Keywords: ***AI-Assisted Inquiry Discovery Learning; Artificial Intelligence; Inquiry Learning; Discovery Learning; critical thinking; creativity.***

INTRODUCTION

The development of 21st-century education requires learning approaches that enable students to develop higher-order thinking skills, particularly critical thinking and creativity. Critical thinking helps students analyze information, evaluate evidence, identify problems, and formulate reasoned judgments, whereas creativity enables them to generate ideas, explore alternatives, and develop original solutions. These competencies are essential for preparing students to respond to complex and rapidly changing situations. However, their development requires learning experiences that actively engage students in questioning, investigation, problem-solving, and reflection rather than relying primarily on information delivery and memorization (Vincent-Lancrin et al., 2019; Lestari & Hindun, 2024).

Inquiry Learning and Discovery Learning offer pedagogical approaches that can support these competencies. Inquiry Learning emphasizes the formulation of questions, investigation of problems, and examination of evidence, while Discovery Learning encourages students to explore information, recognize patterns, and construct knowledge through discovery. Their integration can provide opportunities for students to investigate problems systematically and develop their own understanding. Nurdin et al. (2019) discussed the implementation of inquiry-discovery learning, while Alanazi et al. (2025) highlighted the relevance of guided discovery and scaffolding for developing higher-order thinking. Nevertheless, the effectiveness of these approaches depends on the organization of learning activities and the guidance provided to students throughout the learning process.

Constructivism provides a theoretical foundation for this integration because it views learning as an active process through which students construct knowledge by connecting prior understanding with new experiences. From this perspective, teachers facilitate learning by providing guidance, learning resources, and appropriate scaffolding, while students participate actively in exploring problems and constructing meaning. Integrating inquiry and discovery within a constructivist framework can therefore create learning experiences that encourage students to

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question information, evaluate alternative explanations, and develop their own ideas (Estede et al., 2025; Nurdin et al., 2019).

The development of artificial intelligence (AI) offers additional opportunities to support these learning processes. AI can provide information, suggest alternative perspectives, generate guiding questions, and offer feedback that helps students explore problems from different viewpoints. Research on AI-supported and personalized learning has discussed the potential of AI to support adaptive learning experiences and student engagement (bin Salem, 2024; Mahmoud & Sørensen, 2024). More specifically, AI-supported inquiry can provide opportunities for students to extend their questioning and exploration processes (da Ponte, 2025). However, these opportunities depend on how AI is integrated into instruction. When students use AI primarily to obtain immediate answers, they may engage less in independent reasoning, evidence evaluation, and original idea development.

Consequently, AI should be positioned as a learning support rather than a substitute for students' thinking or teachers' pedagogical roles. Meaningful integration requires students to question AI-generated information, verify its accuracy, compare suggestions with available evidence, and formulate conclusions based on their own reasoning. Teachers remain responsible for facilitating learning, monitoring AI use, and guiding students toward responsible and reflective engagement with technology. This approach is consistent with the broader emphasis on developing critical thinking, creativity, and other competencies required in contemporary education (Vincent-Lancrin et al., 2019; Riska et al., 2025).

Although previous studies have discussed inquiry-discovery learning, technology-enhanced instruction, and AI-supported learning, there remains a need for an instructional model that systematically integrates these elements into a coherent sequence of learning activities. In particular, the pedagogical contribution of AI needs to be connected explicitly to problem orientation, inquiry questioning, investigation, discovery, evidence-based decision-making, and reflection. Without such a structure, AI use may remain an additional technological activity rather than an integral part of students' inquiry and discovery processes. Therefore, the development of an AI-Assisted Inquiry Discovery Learning (AI-IDL) model is proposed as an approach that combines constructivist learning principles, Inquiry Learning, Discovery Learning, and purposeful AI support within a structured instructional framework.

This study aims to: (1) analyze existing learning conditions and the needs of teachers and senior high school students regarding the development of critical thinking and creativity; (2)

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develop and validate an AI-IDL model appropriate for the senior high school context; and (3) examine changes in students' critical thinking and creativity following the implementation of the developed model. Through these objectives, the study seeks to contribute a structured instructional model and initial empirical evidence concerning its potential to support critical thinking and creativity in senior high school learning.

LITERATURE REVIEW

Constructivism as the Theoretical Foundation

Constructivism views learning as an active process in which students construct knowledge through experience, interaction, exploration, and reflection. Rather than receiving information passively, students interpret new information in relation to their prior knowledge and develop understanding through meaningful learning activities. In classroom practice, this perspective requires learning environments that encourage students to formulate questions, investigate problems, discuss interpretations, and evaluate their understanding. The teacher facilitates this process by providing appropriate resources, guidance, and scaffolding.

Within the AI-IDL model, constructivism serves as the overarching theoretical foundation for organizing student-centered learning. Students are expected to participate actively in constructing knowledge, while teachers facilitate inquiry and discovery without immediately providing final answers. AI can function as an additional learning resource, but students remain responsible for interpreting information, evaluating evidence, and constructing their conclusions. This positioning preserves the active role of students in the learning process while allowing technology to support exploration and reflection.

Inquiry Learning and Discovery Learning

Inquiry Learning emphasizes the process of identifying problems, formulating questions, gathering information, examining evidence, and developing explanations. Through these activities, students learn to approach problems systematically and justify their conclusions using relevant information. Discovery Learning complements this process by encouraging students to explore relationships, identify patterns, generate ideas, and construct concepts from their investigations. The integration of inquiry and discovery can therefore connect the formulation of questions with the exploration and development of possible explanations. Nurdin et al. (2019)

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examined inquiry-discovery learning, while Alanazi et al. (2025) emphasized guided discovery and scaffolding in the development of higher-order thinking.

In AI-IDL, Inquiry Learning and Discovery Learning are integrated into a sequence of complementary stages. Inquiry provides the direction for investigation, whereas discovery supports the development of insights and possible solutions. Students are guided to move from identifying a problem and formulating questions to investigating information, generating ideas, evaluating evidence, and communicating conclusions. This sequence is intended to ensure that learning involves not only information gathering but also reasoning, discovery, and reflection.

Artificial Intelligence as Learning Support

AI can support learning by providing access to information, offering alternative explanations, generating guiding questions, and supplying feedback during students' exploration of a problem. Research on AI-supported personalized learning and adaptive technology has discussed the potential of AI to respond to students' learning needs and support educational processes (bin Salem, 2024; Mahmoud & Sørensen, 2024; Riska et al., 2025). In inquiry-oriented learning, AI may also help students broaden their perspectives and explore questions that emerge during investigation (da Ponte, 2025).

However, the educational value of AI depends on its pedagogical function and how students use the information it provides. AI-generated responses should not automatically be treated as accurate or conclusive. Students need to evaluate the relevance and reliability of the information, compare it with other sources, and justify their conclusions with evidence. Accordingly, AI-IDL positions AI as a scaffold for inquiry and discovery rather than as a replacement for independent thinking, teacher guidance, or student decision-making. This distinction is central to the model's design: AI supports the learning process, while students remain actively responsible for their reasoning and ideas.

Critical Thinking and Creativity

Critical thinking involves examining information, analyzing claims, evaluating evidence, identifying assumptions, and developing reasoned conclusions. It requires students to go beyond accepting information at face value and instead determine whether explanations and proposed solutions are adequately supported. Creativity, meanwhile, involves generating ideas, exploring alternative possibilities, developing original responses, and improving ideas in relation to a

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particular problem. Although these competencies have distinct characteristics, they can complement each other in problem-solving activities. Critical thinking helps students evaluate and refine ideas, while creativity supports the generation of alternative approaches and possible solutions (Vincent-Lancrin et al., 2019).

The AI-IDL model is designed to provide opportunities for the development of both competencies through connected learning activities. Problem orientation and inquiry questioning encourage students to identify issues and clarify what needs to be investigated. Investigation and exploration support information analysis and evidence evaluation. Discovery and idea generation create opportunities to develop alternative explanations and solutions. Evidence-based solution activities require students to justify their choices, while reflection and communication encourage them to evaluate and explain their conclusions. In this way, critical thinking and creativity are addressed as complementary learning outcomes rather than as isolated skills.

Conceptual Integration of the AI-IDL Model

The AI-IDL model integrates constructivism, Inquiry Learning, Discovery Learning, and AI-supported learning within a structured instructional framework. Constructivism provides the theoretical foundation; Inquiry Learning guides questioning and investigation; Discovery Learning supports exploration and idea development; and AI provides supplementary information, prompts, alternative perspectives, and feedback. The teacher facilitates the process, monitors the use of AI, and provides scaffolding, while students remain responsible for investigating problems, evaluating evidence, developing ideas, and communicating conclusions.

The model consists of six stages: (1) Problem Orientation, (2) Inquiry Questioning, (3) Investigation and Exploration, (4) Discovery and Idea Generation, (5) Evidence-Based Solution, and (6) Reflection and Communication. These stages connect problem identification with inquiry, discovery, evidence-based reasoning, and reflective learning. The conceptual integration of these theoretical and pedagogical elements is presented in Figure 1.

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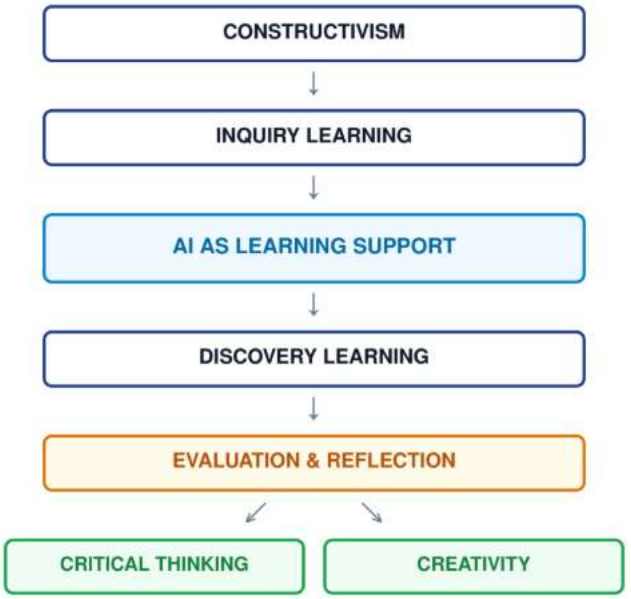


Figure 1 Conceptual Framework of AI-IDL Model

The conceptual framework provides the basis for developing the model's instructional stages and supporting components. Its central proposition is that the structured integration of inquiry, discovery, and responsible AI support may create learning opportunities that promote critical thinking and creativity. The present study therefore examines the model's development and expert validity, as well as changes in these two outcomes following implementation.

METHOD

Research Design and Development Procedure

This study employed a Research and Development (R&D) approach to develop and evaluate an AI-Assisted Inquiry Discovery Learning (AI-IDL) model for senior high school learning. The development process was adapted from established R&D approaches, which emphasize systematic product development, validation, revision, and evaluation (Gustiani, 2019; Pugu et al., 2024; Purba, 2024). The procedure consisted of needs analysis, theoretical and literature review, conceptual design, model and instructional development, expert validation, revision, implementation preparation, implementation, and evaluation.

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The development of the AI-Assisted Inquiry Discovery Learning (AI-IDL) model followed a systematic procedure consisting of needs analysis, theoretical and literature review, conceptual design, model and instructional development, expert validation, revision, implementation preparation, implementation, and evaluation.. The needs analysis was conducted to identify existing learning conditions and the needs of teachers and students related to learning that supports *critical thinking*, *creativity*, and the purposeful use of AI. This stage involved 12 senior high school teachers of Economics Education and 240 senior high school students. Data were collected using Likert-scale questionnaires and analyzed descriptively using frequencies, percentages, means, and standard deviations. The findings were used as a basis for determining the essential characteristics and components of the AI-IDL model. The overall research and development procedure used in this study is presented in Figure 2.

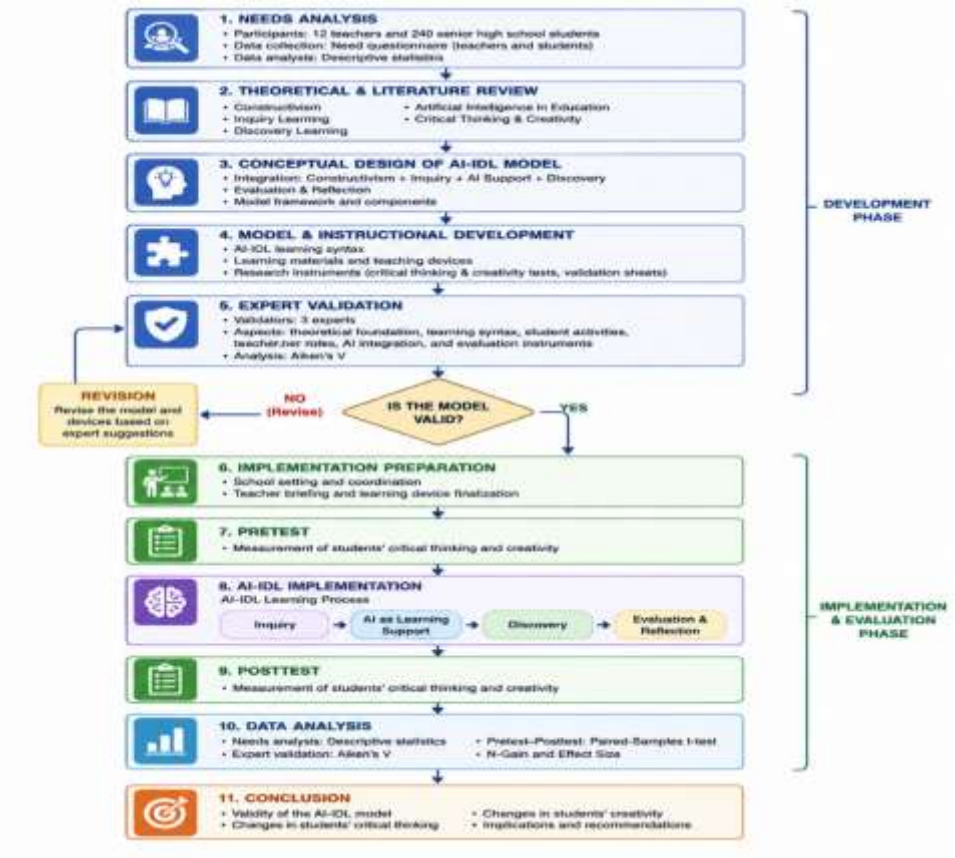


Figure 2 Research and Development Procedure of AI-IDL Model

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Needs Analysis and Participants

The needs-analysis stage involved 12 senior high school teachers who teach Economics and 240 senior high school students. The teacher respondents provided information about instructional needs and the challenges associated with supporting students' critical thinking and creativity. The student respondents provided information about their learning needs in relation to these competencies. The teacher subject area applies to the teacher respondents in the needs analysis and does not, by itself, define the subject in which the AI-IDL model was implemented.

Data were collected using Likert-scale questionnaires designed to identify perceived learning needs related to critical thinking and creativity. The data were analyzed descriptively using frequencies, percentages, means, and standard deviations, as appropriate. Student responses were summarized across five critical-thinking-related indicators and four creativity-related indicators, while teacher responses were summarized across 12 indicators. The results were used to inform the model's design and instructional support requirements.

AI-IDL Model Design and Development

The AI-IDL model was designed by integrating constructivist learning principles, Inquiry Learning, Discovery Learning, and AI as a learning support. The model comprises six stages: Problem Orientation, Inquiry Questioning, Investigation and Exploration, Discovery and Idea Generation, Evidence-Based Solution, and Reflection and Communication. Each stage was designed to provide a connected sequence of student learning activities, with the teacher acting as a facilitator and scaffold provider.

AI was incorporated to support the learning process through information provision, guiding questions, alternative perspectives, feedback, and prompts for further exploration. Students were expected to examine AI-generated information critically, verify relevant claims, consider alternative explanations, and formulate their own evidence-based conclusions. AI was not positioned as a substitute for students' reasoning or as the final authority for answers. This design was intended to preserve student agency and encourage the responsible use of AI throughout inquiry and discovery activities.

Expert Validation and Revision

The developed AI-IDL model was evaluated by three expert validators to examine the relevance and adequacy of its components. The validation covered the model's theoretical

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foundation, instructional stages, learning activities, teacher and student roles, supporting components, integration of AI, and alignment with the intended learning outcomes. Expert ratings were analyzed using Aiken's V to assess the content validity of the model components.

The validation results were used to identify aspects requiring improvement. Revisions were made based on the experts' evaluations before the model proceeded to the implementation stage. This process was intended to strengthen the model's theoretical coherence, instructional clarity, and suitability for its intended educational context.

Implementation and Evaluation

The effectiveness evaluation involved 240 senior high school students using a one-group pretest–posttest design. Students completed assessments of critical thinking and creativity before and after the implementation of the AI-IDL model. The pretest and posttest scores were recorded as CT_Pre and CT_Post for critical thinking, and CR_Pre and CR_Post for creativity.

The data were analyzed using descriptive statistics to summarize students' scores before and after implementation. Paired-samples t-tests were used to examine differences between pretest and posttest scores for each outcome. Normalized gain (N-Gain) was calculated to describe the relative improvement in students' scores, and effect sizes were used to characterize the magnitude of the observed changes. Statistical significance was evaluated at the .05 level.

Because the evaluation used a one-group pretest–posttest design without a control group, the findings were interpreted as evidence of changes observed following implementation rather than definitive proof that the AI-IDL model alone caused those changes. The combination of needs analysis, expert validation, and implementation data provided the basis for evaluating the model's development, validity, and initial empirical outcomes.

RESULT AND DISCUSSION

Current Learning Conditions and Needs Analysis

The needs analysis was conducted as the initial stage in developing the AI-Assisted Inquiry Discovery Learning (AI-IDL) model. This stage involved 240 senior high school students and 12 senior high school teachers who teach Economics. Data were collected using needs-analysis questionnaires and analyzed descriptively using means and standard deviations. The analysis examined students' perceived needs for learning activities that support critical thinking and creativity, as well as teachers' perceived needs for an appropriate instructional model.

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The results showed that the five indicators related to students' critical-thinking learning needs had mean scores ranging from 3.0177 to 3.0521, with an overall mean of 3.0338. The four indicators related to creativity learning needs ranged from 3.0007 to 3.0275, with an overall mean of 3.0131. Based on the interpretation criteria applied in this study, these results indicate a moderate level of perceived need among students. The findings suggest the importance of providing learning experiences that encourage students to identify problems, explore information, evaluate evidence, consider alternative perspectives, and develop ideas. These learning activities are consistent with the emphasis on critical thinking and creativity as essential competencies in twenty-first-century education (Lestari & Hindun, 2024; Vincent-Lancrin et al., 2019).

The teacher needs analysis showed higher mean scores. Across the 12 indicators, scores ranged from 3.9167 to 4.1250, with an overall mean of 4.0246. According to the interpretation criteria used in this study, these results indicate a high perceived need for an instructional model that supports the development of students' critical thinking and creativity. The findings highlight the importance of providing teachers with a structured approach to facilitating student investigation, information exploration, idea development, and purposeful technology use. This need aligns with the emphasis on integrating twenty-first-century competencies into instructional practices and designing learning environments that respond to students' learning needs (Aziz et al., 2024; Riska et al., 2025).

Table 1. Summary of Needs Analysis Results

Respondent	Aspect of Need	N	Number of Indicators	Mean Range	Overall Mean	Interpretation
Students	Critical thinking	240	5	3.0177-3.0521	3.0338	Moderate
Students	Creativity	240	4	3.0007-3.0275	3.0131	Moderate
Teachers	Instructional model development	12	12	3.9167-4.1250	4.0246	High

The needs analysis provided an empirical basis for determining the principal characteristics of AI-IDL. The findings suggest the relevance of an instructional model that goes

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beyond providing access to technology and systematically guides students through problem investigation, information processing, evidence evaluation, discovery, and idea development. Accordingly, AI was incorporated as a learning support that can provide information, guiding prompts, alternative perspectives, and feedback while maintaining students' active involvement in learning. This orientation is consistent with research on AI-supported and adaptive learning, which emphasizes the importance of aligning technological support with pedagogical objectives (bin Salem, 2024; Riska et al., 2025). Thus, the first research question was addressed by identifying the perceived needs of students and teachers that informed the design of the AI-IDL model.

AI-IDL Model Development and Expert Validation

The AI-Assisted Inquiry Discovery Learning (AI-IDL) model was developed based on the identified learning needs and the theoretical framework established through the literature review. The model integrates constructivism as its theoretical foundation, *Inquiry Learning* and *Discovery Learning* as its pedagogical foundations, and Artificial Intelligence (AI) as a learning support. This integration positions students as active participants in constructing knowledge through investigation, exploration, discovery, evaluation, and reflection.

The resulting model consists of six learning stages: (1) Problem Orientation, (2) Inquiry Questioning, (3) Investigation and Exploration, (4) Discovery and Idea Generation, (5) Evidence-Based Solution, and (6) Reflection and Communication. During Problem Orientation, students are introduced to contextual problems and encouraged to identify the main issues to be investigated. In Inquiry Questioning, they formulate questions to guide their investigation. Investigation and Exploration involves searching for relevant information, examining evidence, and using AI purposefully to expand exploration. During Discovery and Idea Generation, students identify patterns, concepts, possible explanations, and alternative ideas based on the information they have examined. Evidence-Based Solution requires students to formulate and justify solutions using relevant evidence. Finally, Reflection and Communication allows students to evaluate their learning process, communicate their findings, and reflect on the solutions they have developed.

The role of AI is deliberately structured across the learning process so that it does not become a substitute for students' thinking or the final source of answers. AI can provide prompts, information, alternative perspectives, and feedback; however, students remain responsible for questioning, verifying information, evaluating evidence, making judgments, and constructing

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conclusions. This design reflects the principles of *Inquiry-Discovery Learning*, which engage students in mental processes through which knowledge is actively constructed (Nurdin et al., 2019). It also aligns with *guided discovery* and *scaffolding*, which provide appropriate support while maintaining students' active involvement in higher-order thinking (Alanazi et al., 2025). The model therefore integrates AI into a pedagogically structured process rather than treating it as an independent technological tool.

The developed model was evaluated by three expert validators. The validation covered the theoretical foundation, learning syntax, student activities, teacher roles, AI integration, and evaluation instruments. The validity of the model was assessed using Aiken's V.

Table 2. Expert Validation Results for the AI-IDL Model

Validation Component	Number of Validators	Minimum Aiken's V	Maximum Aiken's V	Mean Aiken's V	Interpretation
AI-IDL model and supporting components	3	0.833	1.000	0.924	High content validity

The Aiken's V coefficients ranged from 0.833 to 1.000, with an overall mean of 0.924. These results indicate a high level of expert agreement regarding the content validity of the AI-IDL model and its supporting components. The validation findings support the appropriateness of the model's theoretical foundation, learning syntax, student and teacher activities, and integration of AI. The results also provided a basis for revising the model before implementation.

The revision process focused on improving the clarity and consistency of the learning stages, the alignment between teacher and student activities, the role of AI throughout the learning process, and the suitability of the supporting instruments. Expert validation therefore served not only to assess content validity but also to refine the model's pedagogical coherence and practical suitability. This process is consistent with educational research and development approaches, in which expert assessment and revision are used to improve an instructional product before implementation (Gustiani, 2019; Pugu et al., 2024).

The second research question was addressed through the development and expert validation of a six-stage AI-IDL model. The mean Aiken's V coefficient of 0.924 provides evidence

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of high content validity under the criteria used in this study. However, expert validation establishes the appropriateness of the model's content and design; its learning outcomes must be examined separately through implementation data.

Effectiveness of AI-IDL Implementation

Following expert validation and revision, the AI-IDL model was implemented with 240 senior high school students using a one-group pretest–posttest design. Students' critical thinking and creativity were measured before and after implementation. The descriptive results are presented in Table 3.

Table 3. Student's Critical and Creativity Scores Before and Aftre AI-IDL Implementation

Variable	N	Pretest Mean	Posttest Mean	Mean Improvement
Critical Thinking	240	62.1542	79.1625	17.0083
Creativity	240	60.2042	75.3625	15.1583

The mean critical-thinking score increased from 62.1542 at pretest to 79.1625 at posttest, representing an improvement of 17.0083 points. Similarly, the mean creativity score increased from 60.2042 to 75.3625, representing an improvement of 15.1583 points. These descriptive findings show positive changes in both measured outcomes following participation in the AI-IDL learning process.

Paired-samples t-tests were conducted to examine whether the pretest–posttest differences were statistically significant. N-Gain values and effect sizes were also examined to characterize the observed improvements. The results are presented in Table 4.

Table 4. Paired-Sample t-Test, N-Gain, and Effect Size Results

Variable	*t*	*df*	*p*	N-Gain	N-Gain Interpretation	Cohen's (d z)	Effect Interpretation
Critical Thinking	46.284	239	<0.001	0.4690	Moderate	2.99	Very large
Creativity	32.730	239	<0.001	0.3978	Moderate	2.11	Very large

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The paired-samples t-test indicated a statistically significant difference between the pretest and posttest critical-thinking scores, ($t(239) = 46.284$), ($p < .001$). The N-Gain value of 0.4690 indicates moderate normalized improvement, while Cohen's (d_z) of 2.99 indicates a very large standardized change. These results suggest that students' critical-thinking scores increased substantially during the period in which AI-IDL was implemented.

This improvement can be considered in relation to the cognitive activities incorporated into AI-IDL. Students were guided to identify problems, formulate questions, explore information, examine evidence, evaluate alternative explanations, and develop evidence-based solutions. Such activities provide opportunities to practice analysis, evaluation, inference, and reasoned decision-making. They are consistent with the emphasis on deliberately designed learning experiences for developing critical thinking (Vincent-Lancrin et al., 2019). The integration of inquiry and discovery also encourages students to construct conclusions through investigation rather than simply receive predetermined answers (Nurdin et al., 2019). In addition, AI-supported inquiry may broaden opportunities for students to formulate questions, explore information, and consider alternative perspectives (da Ponte, 2025).

For creativity, the paired-samples t-test also indicated a statistically significant difference between pretest and posttest scores, ($t(239) = 32.730$), ($p < .001$). The N-Gain value of 0.3978 indicates moderate normalized improvement, while Cohen's (d_z) of 2.11 indicates a very large standardized change. The mean creativity score increased by 15.1583 points following implementation. These findings indicate a substantial positive change in students' measured creativity scores during their participation in the AI-IDL learning process.

The observed improvement can be considered in relation to the Discovery and Idea Generation stage, which encourages students to explore possibilities, identify relationships, generate alternatives, and develop or refine ideas. AI can serve as a stimulus by providing additional information and alternative perspectives. Nevertheless, students remain responsible for selecting relevant information, combining ideas, and developing their own solutions. This approach aligns with the importance of learning environments that give students opportunities to generate, evaluate, and develop ideas (Vincent-Lancrin et al., 2019). It is also consistent with research examining instructional approaches intended to support creativity and critical thinking (Azizah & Angelina, 2025).

Taken together, the results suggest that the potential contribution of AI-IDL lies in the structured integration of AI into inquiry and discovery processes. AI supports information

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exploration, question formulation, alternative perspectives, and feedback, while students remain responsible for verifying information, evaluating evidence, making decisions, and constructing solutions. The findings therefore underscore the importance of pedagogical design in determining how AI is used during learning. This orientation is consistent with research on personalized and adaptive learning, which emphasizes aligning AI-based support with appropriate learning objectives (bin Salem, 2024; Mahmoud & Sørensen, 2024; Riska et al., 2025).

The principal contribution of this study is the development of a six-stage instructional model that specifies how AI can support inquiry and discovery without replacing students' cognitive responsibilities. Constructivism provides the foundation for active knowledge construction, inquiry structures questioning and investigation, discovery supports the identification and development of concepts and solutions, and AI broadens the support available during exploration. Together, these elements provide a coherent framework for engaging students in investigating problems, evaluating information, developing ideas, and reflecting on their learning. This contribution emphasizes the importance of embedding technology within purposeful instructional design rather than treating technology use as an educational outcome in itself (Lee & Lee, 2025; Mahmudah & Izzah, 2025).

Despite these promising findings, the results should be interpreted in light of the study design. The evaluation employed a one-group pretest–posttest design without a control group. Although both outcomes showed statistically significant increases and very large standardized changes, the design does not establish that AI-IDL alone caused the observed improvements. Other factors, including students' broader learning experiences, maturation, or familiarity with the assessment instruments, may also have contributed. Further studies using experimental or quasi-experimental designs with comparison groups are needed to examine the model's effectiveness more rigorously. Research across different subjects, schools, and student populations would also help establish the applicability of the model in varied educational contexts.

Overall, the findings address the three research questions. First, the needs analysis identified students' and teachers' perceived learning needs that informed the development of an instructional model integrating inquiry, discovery, and AI support. Second, the six-stage AI-IDL model achieved a mean Aiken's V coefficient of 0.924, indicating high content validity according to the criteria adopted in this study. Third, students' critical-thinking and creativity scores increased significantly following implementation, with moderate N-Gain values and very large

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standardized changes. These results provide initial empirical support for AI-IDL as a structured instructional model with potential to support critical thinking and creativity among senior high school students.

CONCLUSION

This study developed the AI-Assisted Inquiry Discovery Learning (AI-IDL) model in response to identified needs for learning experiences that support students' critical thinking and creativity. The model integrates constructivism as its theoretical foundation, Inquiry Learning and Discovery Learning as its pedagogical foundations, and artificial intelligence as a learning support. The model comprises six stages: Problem Orientation, Inquiry Questioning, Investigation and Exploration, Discovery and Idea Generation, Evidence-Based Solution, and Reflection and Communication. Expert validation yielded a mean Aiken's V coefficient of 0.924, indicating high content validity according to the criteria used in this study.

Following implementation, the mean critical-thinking score increased from 62.1542 to 79.1625, with an N-Gain of 0.4690 and a standardized effect size of 2.99. The mean creativity score increased from 60.2042 to 75.3625, with an N-Gain of 0.3978 and a standardized effect size of 2.11. Both outcomes showed statistically significant pretest–posttest differences ($p < .001$). These findings indicate positive changes in students' measured critical thinking and creativity following participation in the AI-IDL learning process.

The principal contribution of AI-IDL is its structured positioning of AI as learning support rather than as a replacement for teachers or a source of final answers. AI provides information, prompts, alternative perspectives, and feedback, while students remain responsible for verification, evaluation, decision-making, solution development, and reflection. Nevertheless, because the implementation evaluation used a one-group pretest–posttest design without a control group, the observed improvements cannot be attributed exclusively to AI-IDL. Further controlled research is required to establish the model's effectiveness more rigorously.

FUTURE DIRECTIONS

Future research should examine AI-IDL across different subjects, educational levels, student characteristics, and school contexts to determine its applicability and transferability. Experimental or quasi-experimental studies incorporating comparison groups and more diverse samples are needed to provide stronger evidence regarding the model's effectiveness.

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Longitudinal studies could also investigate whether improvements in critical thinking and creativity are sustained over time. In addition, further research could examine how students' AI literacy, teachers' instructional competence, and the characteristics of the AI tools used influence the implementation process and learning outcomes. Such work would help refine AI-IDL and clarify the conditions under which its integration of inquiry, discovery, and AI support is most beneficial.

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