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The Effect of Design Thinking-Based Inquiry Learning on Students' Problem-Solving Ability and Creative Thinking Skills in the Circulatory System

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Abstract

Learning the circulatory system requires higher-order thinking skills, particularly problem-solving ability and creative thinking skills. These competencies can be developed through inquiry-based learning integrated with design thinking. This study aimed to analyze the effect of design thinking-based inquiry learning on students' problem-solving ability and creative thinking skills in the circulatory system topic. A quasi-experimental method with a pretest–posttest control group design was employed, involving 62 eleventh-grade students from a public senior high school in Tangerang Regency, Banten Province. The experimental group implemented inquiry-based learning based on design thinking, while the control group applied discovery learning based on the scientific approach. Data were collected using essay tests measuring problem-solving ability and creative thinking skills. The N-Gain scores for problem-solving ability were 0.66 in the experimental group and 0.47 in the control group, while those for creative thinking skills were 0.66 and 0.50, respectively. All scores fell within the moderate category. MANCOVA results indicated a statistically significant effect of the learning model on the combined outcome variables ($p < 0.001$; $\alpha = 0.05$). These findings suggest that inquiry-based learning integrated with design thinking can support the development of students' problem-solving ability and creative thinking skills. Biology teachers are encouraged to integrate design thinking into inquiry-based learning to promote active exploration, idea development, and solution refinement.

Keywords: Inquiry-Based Learning, Design Thinking, Problem-Solving Ability, Creative Thinking Skills.

Pengaruh *Inquiry-Based Learning* Berbasis *Design Thinking* terhadap Kemampuan Pemecahan Masalah dan Keterampilan Berpikir Kreatif Murid pada Materi Sistem Sirkulasi

Abstrak

Pembelajaran sistem sirkulasi memerlukan keterampilan berpikir tingkat tinggi, khususnya kemampuan pemecahan masalah dan keterampilan berpikir kreatif. Kompetensi tersebut dapat dikembangkan melalui pembelajaran berbasis inkuiri yang terintegrasi dengan *design thinking*. Penelitian ini bertujuan untuk menganalisis pengaruh *inquiry-based learning* berbasis *design thinking* terhadap kemampuan pemecahan masalah dan keterampilan berpikir kreatif murid pada materi sistem sirkulasi. Penelitian

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menggunakan metode kuasi eksperimen dengan desain *pretest–posttest control group* yang melibatkan 62 murid kelas XI SMA Negeri di Kabupaten Tangerang, Provinsi Banten. Kelompok eksperimen menerapkan *inquiry-based learning* berbasis *design thinking*, sedangkan kelompok kontrol menerapkan *discovery learning* berbasis pendekatan saintifik. Data dikumpulkan menggunakan tes esai untuk mengukur kemampuan pemecahan masalah dan keterampilan berpikir kreatif. Nilai N-Gain kemampuan pemecahan masalah pada kelompok eksperimen dan kontrol masing-masing sebesar 0,66 dan 0,47, sedangkan nilai N-Gain keterampilan berpikir kreatif masing-masing sebesar 0,66 dan 0,50. Seluruh nilai tersebut termasuk kategori sedang. Hasil MANCOVA menunjukkan adanya pengaruh signifikan model pembelajaran terhadap kedua variabel secara simultan ($p < 0,001$; $\alpha = 0,05$). Temuan ini menunjukkan bahwa *inquiry-based learning* berbasis *design thinking* dapat mendukung pengembangan kemampuan pemecahan masalah dan keterampilan berpikir kreatif murid. Guru biologi disarankan mengintegrasikan *design thinking* dalam pembelajaran berbasis inkuiri untuk mendorong eksplorasi aktif, pengembangan gagasan, dan penyempurnaan solusi.

Kata kunci : *Inquiry-Based Learning*, *Design Thinking*, Kemampuan Pemecahan Masalah, Keterampilan Berpikir Kreatif.

INTRODUCTION

The demands of 21st-century education have expanded beyond the 4C framework to encompass the 6C competencies: critical thinking, creativity, collaboration, communication, character, and citizenship. These competencies require students to develop higher-order thinking skills and apply knowledge meaningfully to address complex problems (Rusmansyah et al., 2026). Consequently, educational practices need to emphasize conceptual understanding rather than rote memorization. Inquiry-based learning provides opportunities for students to investigate questions, examine evidence, and construct scientific understanding through active learning. A recent meta-analysis confirmed that inquiry-based learning has a positive effect on students' conceptual understanding in science and mathematics (Mediana et al., 2025).

Creative thinking skills enable students to generate multiple perspectives, possibilities, and alternative approaches to solving problems. These skills are essential for addressing increasingly complex global challenges in a rapidly advancing technological era. According to Nugraha et al. (2023), creative students demonstrate flexibility, originality, and the ability to design their own solutions to problems. Creative thinking also serves as a means of preparing individuals to cope with authentic problems encountered in everyday life (Saputra, 2020). Azzahra et al. (2023) highlighted several benefits of creative thinking, including facilitating personal growth

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in problem-solving, generating useful outcomes, providing psychological satisfaction, and enabling individuals to achieve their fullest potential. Furthermore, creative thinking is considered a complex construct involving cognitive, social, and personality-related dimensions (Nakano & Wechsler, 2018).

Problem-solving ability is an essential component of higher-order thinking skills, involving the identification and interpretation of problems, analysis of relevant information, evaluation of alternative solutions, and selection of appropriate strategies. Developing this ability requires learning experiences that engage students in reasoning, evaluating evidence, and applying knowledge to solve complex problems. Recent research emphasizes the importance of assessing students' problem-solving processes, rather than focusing exclusively on final answers, to better understand their reasoning and problem-solving competencies (Hadi & Csíkos, 2026). Problem-solving ability is an essential component of higher-order thinking skills. It involves identifying problems, formulating relevant questions, analyzing available information, considering alternative solutions, and drawing appropriate conclusions. In biology education, problem-solving skills can be developed through learning activities that engage students in addressing contextual problems and systematically evaluating possible solutions. Previous studies have examined students' problem-solving skills through problem-based learning and biology learning approaches designed to strengthen these competencies (Hidayati et al., 2022; Fatmawati et al., 2024). These findings underscore the importance of providing meaningful learning experiences that enable students to apply biological knowledge to solve problems.

The contribution of this study lies in examining the integration of inquiry-based learning and design thinking to develop students' problem-solving ability and creative thinking skills simultaneously in circulatory system learning. The integrated model connects scientific investigation with problem definition, idea generation, solution development, and testing. These processes provide complementary learning experiences: problem-solving is supported by systematic problem identification and solution evaluation, whereas creative thinking is fostered through the generation and refinement of diverse ideas. The study further examines these outcomes while controlling for students' initial abilities, providing evidence of the model's effect on both competencies in a biology learning context.

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Previous studies have reported limitations in existing instructional practices. Zohar and Dori (2003) found that learning environments that do not explicitly promote higher-order thinking tend to produce only superficial understanding. Similarly, Hidayat et al. (2020) reported that the implementation of discovery learning at the secondary school level did not significantly improve students' creative thinking skills because learning activities did not sufficiently encourage the generation of original and diverse ideas. Rahman (2019) also revealed that students' problem-solving ability remained at a moderate to low level due to instructional practices that inadequately emphasized the analysis of complex problems and data-driven decision-making. These findings indicate a mismatch between the demands of 21st-century skills and the instructional models commonly implemented in schools.

Problem-solving ability and creative thinking skills are important competencies in biology learning because they support students in analyzing problems, evaluating alternatives, and developing appropriate solutions. Problem-solving enables students to approach problems systematically, whereas creative thinking encourages the generation of diverse and original ideas. These competencies are closely related and can be developed through learning activities that engage students in investigating problems and exploring possible solutions. Previous research has reported a relationship between problem-solving ability and creative thinking skills in learning the human circulatory system (Leasa et al., 2021). Furthermore, integrating creative pedagogy into problem-based learning has been found to support higher-order thinking skills, including analytical reasoning and innovative problem-solving, in science education (Integrating Creative Pedagogy into Problem-Based Learning, 2024).

One instructional model that has the potential to enhance students' problem-solving ability and creative thinking skills is inquiry-based learning integrated with design thinking. Inquiry-based learning focuses on questioning, investigating, and acquiring knowledge through the exploration of problems (Mulyani, 2023). According to Baeti and Mikrayanti (2021), inquiry-based learning requires students to construct their own knowledge through investigation, inquiry, and experimentation. This approach aims to engage students in authentic scientific discovery processes (Pedaste et al., 2015). As a student-centered learning model, inquiry-based learning promotes creativity, innovation, problem-solving, information seeking, and collaborative skills

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(Maknun & Haryanti, 2022).

The effectiveness of inquiry-based learning may be enhanced when integrated with instructional approaches that share similar objectives. One such approach is design thinking. Wulandari et al. (2023) described design thinking as a solution-oriented problem-solving approach. Satria and Muntaha (2022) further defined design thinking as a mechanism for generating creative ideas. Design thinking combines structured processes with a human-centered orientation, ensuring that solutions provide meaningful value and benefits to users. This approach emphasizes not only observable phenomena but also individuals' experiences and perspectives (Sari et al., 2020). Moreover, design thinking involves examining existing concepts, conducting investigations to solve problems, and promoting students' cognitive development (Azizah, 2024). Unlike previous studies, the present study integrates design thinking into inquiry-based learning to simultaneously examine students' problem-solving ability and creative thinking skills in the context of the human circulatory system. Furthermore, this study compares the integrated approach with discovery learning based on the scientific approach and analyzes its effects on both competencies while controlling for students' pretest scores. Therefore, the distinctive contribution of this study lies in examining the integration of inquiry-based learning and design thinking as an approach to developing both problem-solving ability and creative thinking skills in biology learning.

The integration of inquiry-based learning and design thinking is expected to improve students' problem-solving ability and creative thinking skills in learning the circulatory system. The circulatory system topic, particularly concepts related to its structures, physiological processes, and disorders, involves complex and interconnected concepts that require deep conceptual understanding and higher-order thinking skills (Gregorčič & Torkar, 2022). Inquiry-based learning integrated with design thinking is considered particularly suitable for this topic because it encourages students to construct knowledge through systematic inquiry, connect scientific concepts to contextual problems, and design solutions based on scientific analysis of circulatory system disorders. Previous research has demonstrated the relevance of guided inquiry for circulatory system instruction in developing students' critical thinking skills (Wulandari et al., 2022). In addition, Leasa et al. (2021) examined problem-solving and creative

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thinking skills in the context of the human circulatory system using problem-based learning. Building on these studies, the present study integrates inquiry-based learning with design thinking and examines its effects on students' problem-solving ability and creative thinking skills simultaneously, compared with discovery learning based on the scientific approach. This integration is expected to provide opportunities for students to investigate biological problems systematically, generate alternative ideas, and develop evidence-based solutions to problems related to the circulatory system.

The integration of inquiry-based learning and design thinking facilitates students' active engagement in analyzing structure–function relationships within the circulatory system, understanding blood circulation mechanisms, and exploring multiple solutions creatively and logically. Consequently, this integrated approach may promote more meaningful learning and support the development of 21st-century competencies. Therefore, this study aimed to analyze the effect of inquiry-based learning integrated with design thinking on students' problem-solving ability and creative thinking skills in learning the human circulatory system.

RESEARCH METHODS

This study employed a quasi-experimental method using a pretest–posttest control group design. The research was conducted at SMAN 22 Tangerang Regency, Banten Province, Indonesia, during the second semester of the 2025/2026 academic year. The study examined the effects of inquiry-based learning integrated with design thinking on students' problem-solving ability and creative thinking skills in the human circulatory system topic. The experimental group received inquiry-based learning integrated with design thinking, whereas the control group received Discovery Learning based on the scientific approach.

The population consisted of 74 eleventh-grade students from four classes: XI FC-1, XI FC-2, XI FD-1, and XI FD-2. The school was selected through purposive sampling based on its relevance to the research objectives. Two classes were subsequently selected using cluster random sampling. The sample size was determined using the Taro Yamane formula with a 5% precision level, resulting in 62 students. Simple random sampling was used to select the participants, comprising 31 students in the experimental group and 31 students in the control group.

The intervention was implemented over three meetings, totaling nine instructional

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hours, and covered circulatory organs, blood circulation processes, and circulatory system disorders. The experimental group received inquiry-based learning integrated with design thinking, incorporating the processes of empathizing, defining problems, generating ideas, developing prototypes, and testing solutions. The control group received Discovery Learning based on the scientific approach, comprising stimulation, problem statement, data collection, data processing, verification, and generalization. Both groups studied the same material but received different instructional approaches.

Data were collected using essay tests administered before and after the instructional intervention. Problem-solving ability was measured using four indicators based on Polya's framework: understanding the problem, devising a plan, carrying out the plan, and looking back. Creative thinking skills were measured using four indicators associated with Guilford's framework: fluency, flexibility, originality, and elaboration. The pretests assessed students' initial abilities, while the posttests measured their abilities following the intervention.

Instrument validity was examined using the Pearson product–moment correlation, with a critical correlation value ((r_{\text{table}})) of 0.361. Seven of the eight problem-solving test items were valid, while one item was invalid. For the creative thinking test, six of the eight items were valid, while two items were invalid. Reliability was assessed using Cronbach's alpha, yielding coefficients of 0.648 for the problem-solving instrument and 0.694 for the creative thinking instrument. Both coefficients exceeded the study's reliability criterion of 0.60.

Data were analyzed using SPSS version 25. Descriptive statistics, including the mean, standard deviation, variance, minimum score, and maximum score, were used to summarize students' performance. Learning improvement was assessed using the normalized gain (N-Gain). Before hypothesis testing, statistical assumptions were examined using the Shapiro–Wilk test for normality, Levene's test for homogeneity of variance, the Run Test for randomness, and the Glejser test for heteroscedasticity. Linearity was also examined as required for the planned analysis. Multivariate analysis of covariance (MANCOVA) was conducted at a significance level of 0.05 to determine the simultaneous effects of the learning approach on problem-solving ability and creative thinking skills while controlling for the corresponding pretest scores.

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RESULTS AND DISCUSSION

Descriptive statistical analysis showed improvements in both problem-solving ability and creative thinking skills in the experimental and control groups following the instructional intervention. For problem-solving ability, the experimental group's mean score increased from 49.87 to 82.80, with an N-Gain of 0.66, whereas the control group's mean score increased from 41.32 to 69.03, with an N-Gain of 0.47. Both groups demonstrated moderate improvement, although the experimental group achieved a higher N-Gain. A similar pattern was observed for creative thinking skills: the experimental group's mean score increased from 48.83 to 82.67, with an N-Gain of 0.66, while the control group's mean score increased from 41.77 to 71.03, with an N-Gain of 0.50. These descriptive findings indicate that students receiving inquiry-based learning integrated with design thinking showed greater gains in both measured competencies than those receiving Discovery Learning based on the scientific approach. However, the statistical significance of the differences should be interpreted based on the inferential analysis.

The greater gains in the experimental group may be associated with the complementary roles of inquiry-based learning and design thinking. Inquiry-based learning encourages students to investigate questions, gather evidence, and construct explanations, while design thinking provides structured opportunities to define problems, generate alternative ideas, develop prototypes, and test possible solutions. These activities are relevant to problem-solving because students must identify problems, plan approaches, evaluate evidence, and consider the adequacy of their solutions. The ideation process may also support creative thinking by encouraging students to generate multiple ideas and consider alternative approaches. This interpretation is consistent with Yu et al. (2024), whose meta-analysis reported an overall positive effect of design thinking on student learning, including problem-solving ability and creative thinking. Furthermore, Muneer et al. (2025, published online) reported that design-thinking interventions significantly improved creativity in STEM education. These findings provide a plausible explanation for the higher N-Gain values observed in the experimental group. Nevertheless, because the present study evaluated an integrated learning approach, the observed differences cannot establish the independent contribution of inquiry-based learning or design thinking separately.

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Table 1. Summary of Assumption Tests for MANCOVA

Assumption	Statistical Test	Results	Interpretation
Normality	Shapiro–Wilk	p = 0.227–0.864	Normally distributed
Homogeneity	Levene's Test	p = 0.150–0.766	Homogeneous
Autocorrelation	Runs Test	p = 0.270–0.995	No autocorrelation
Regression Relationship	Linear Regression	p < 0.001	Significant
Homoscedasticity	Glejser Test	p = 0.319–0.746	No heteroscedasticity
Multivariate Linearity	Deviation from Linearity	p = 0.184–0.755	Linear relationship

Based on Table 1, the Shapiro–Wilk test (p = 0.227–0.864), Levene's test (p = 0.150–0.766), Runs test (p = 0.270–0.995), Glejser test (p = 0.319–0.746), and deviation-from-linearity test (p = 0.184–0.755) yielded significance values greater than 0.05. These results indicate that the data met the assessed assumptions of normality, homogeneity of variance, absence of non-random patterns, homoscedasticity, and linearity, supporting further analysis using MANCOVA (Field, 2018; Tabachnick & Fidell, 2019).

Table 2. Results of MANCOVA Analysis

Effect	Wilks' Lambda	Sig.
Problem-solving pretest	0.274	<0.001
Creative thinking pretest	0.475	<0.001
Learning model	0.368	<0.001

Based on Table 2, the MANCOVA results revealed statistically significant effects of the learning model and both pretest scores on the combined posttest outcomes of problem-solving ability and creative thinking skills (p < 0.001). The learning model showed a Wilks' Lambda value of 0.368, with F = 49.024 (p < 0.001), indicating a significant multivariate difference between the inquiry-based learning integrated with design thinking group and the Discovery Learning group after accounting for students' initial abilities. The pretest scores of problem-solving ability (Wilks' Lambda = 0.274; F = 75.470; p < 0.001) and creative thinking skills (Wilks' Lambda = 0.475; F = 31.562; p < 0.001) were also significant covariates. These findings suggest that the learning

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model was associated with differences in the combined learning outcomes beyond students' initial performance. This result is consistent with the meta-analysis by Yu et al. (2024), which reported positive effects of design thinking on student learning, including problem-solving and creative thinking. However, the multivariate result alone does not establish the separate effect of the learning model on each dependent variable; those effects require follow-up univariate analyses.

Table 3. N-Gain of Problem-Solving Indicators

Indicator	**Experimental Group**	**Category**	**Control Group**	**Category**
Understanding Problem	0.97	High	0.88	High
Planning	0.82	High	0.90	High
Implementation	1.00	High	0.75	High
Reviewing	0.48	Moderate	0.58	Moderate

Based on Table 3, both groups demonstrated improvements across all four indicators of Polya's problem-solving framework, although the patterns of improvement differed between groups. The experimental group achieved higher N-Gain values in understanding the problem (0.97) and implementing solutions (1.00) than the control group (0.88 and 0.75, respectively). However, the control group achieved a higher gain in planning solutions (0.90) than the experimental group (0.82). The reviewing indicator showed the lowest gains in both groups, with values of 0.48 in the experimental group and 0.58 in the control group. These results suggest that inquiry-based learning integrated with design thinking was associated with greater improvements in understanding problems and implementing solutions, but not in every problem-solving indicator.

The improvement in problem-solving ability may be explained by the characteristics of inquiry-based learning, which actively engage students in investigating phenomena, formulating questions or hypotheses, collecting evidence, and drawing conclusions. Through these processes, students construct scientific knowledge and develop systematic reasoning skills. Pedaste et al. (2015) described inquiry-based

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learning as a process involving orientation, conceptualization, investigation, conclusion, and discussion, which provides a structured framework for scientific inquiry. Similarly, Hala and Xhomara (2022) reported positive outcomes associated with inquiry-based learning in developing students' learning competencies. In the present study, students investigated contextual problems related to the circulatory system, identified possible causes, and developed evidence-based solutions. These experiences may have helped them connect biological concepts with authentic situations and apply their knowledge when solving problems.

The relatively high gains in understanding the problem and implementing solutions in the experimental group may also be associated with the integration of design thinking into inquiry-based learning. The empathize and define stages encouraged students to explore contextual issues, identify relevant needs, and formulate problems before developing possible solutions. Clear problem definition is important because it helps learners distinguish relevant information and establish an appropriate direction for problem-solving. Cheong et al. (2017) and Kwon et al. (2021) highlighted the importance of problem definition and structured problem-solving processes in learning and design contexts. Furthermore, integrating inquiry with design thinking may help students organize information, analyze relationships among concepts, and develop evidence-based strategies (Rodríguez et al., 2019; Pena et al., 2024). These processes provide a plausible explanation for the high gain in understanding the problem observed in the experimental group.

The highest gain in the implementation indicator (N-Gain = 1.00) may be related to the prototype and test stages of design thinking. During these stages, students develop possible solutions, examine their feasibility, and refine their ideas based on evidence and feedback. Such activities create opportunities to translate conceptual understanding into practical action. Basir and Maharani (2017) and Li and Zhan (2022) reported findings relevant to the role of design-oriented or applied learning activities in supporting students' ability to develop and implement solutions. In the present study, these activities may have helped students apply biological concepts when addressing problems related to blood circulation and disorders of the circulatory system. The positive contribution of design thinking to student learning is also supported by the meta-analysis of Yu et al. (2024), which reported an overall positive effect of design

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thinking, including on problem-solving outcomes.

In contrast, the control group achieved a higher N-Gain in planning solutions (0.90) than the experimental group (0.82). This finding indicates that Discovery Learning also supported students' development of problem-solving strategies. Its stages of problem formulation, data collection, and data processing provide opportunities for students to organize information and determine approaches to scientific questions. Therefore, the results should not be interpreted as showing that the experimental model was superior across all indicators. Instead, the pattern suggests that the two learning approaches may have supported different aspects of problem-solving.

The reviewing indicator showed the lowest gain in both groups, suggesting that evaluating completed solutions and reflecting on the problem-solving process remained challenging. Reviewing requires students to check the accuracy of their answers, evaluate the evidence supporting their conclusions, and consider whether their chosen strategies were effective. This process corresponds to the final stage of Polya's (1957) problem-solving framework, which emphasizes looking back at both the solution and the process used to obtain it. The moderate gains observed in both groups suggest some improvement in students' evaluative skills, but additional instructional support may be needed. Teachers could incorporate structured reflection questions, answer-verification activities, and opportunities for students to justify their solutions with scientific evidence.

From a constructivist perspective, these findings suggest that students may develop problem-solving ability through active engagement with experiences and authentic problems. Inquiry-based learning encourages students to investigate scientific phenomena and construct explanations, while design thinking extends this process by guiding students to define problems, generate ideas, develop prototypes, and test potential solutions. This integration may provide meaningful opportunities for students to identify, analyze, and solve problems rather than merely receive information from the teacher (Pedaste et al., 2015; Rodríguez et al., 2019). Overall, the findings indicate that inquiry-based learning integrated with design thinking was associated with higher gains in understanding problems and implementing solutions, whereas planning and reviewing remain important areas for further improvement. Because these results are

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based on descriptive N-Gain values, the differences between groups for individual indicators should not be considered statistically significant unless supported by appropriate inferential tests.

Table 4. N-Gain of Creative Thinking Indicators

Indicator	**Experimental Group**	**Category**	**Control Group**	**Category**
Fluency	1.00	High	0.70	High
Flexibility	1.00	High	0.62	Moderate
Originality	0.87	High	0.17	Low
Elaboration	0.95	High	-0.08	Low

As presented in Table 4, the experimental group demonstrated higher gains across all creative thinking indicators than the control group. The highest gains were observed in fluency and flexibility, both reaching an N-Gain score of 1.00. Originality and elaboration also showed substantial improvement, with N-Gain values of 0.87 and 0.95, respectively. In contrast, the control group achieved lower gains, particularly in originality (N-Gain = 0.17) and elaboration (N-Gain = -0.08), which were categorized as low. These findings indicate that inquiry-based learning based on design thinking was highly effective in fostering students' ability to generate diverse ideas, develop original solutions, and elaborate their thinking.The significant increase in fluency and flexibility may be explained by the ideation stage of design thinking, during which students were encouraged to generate multiple ideas and alternative solutions without immediate evaluation. Such activities created a supportive environment that reduced students' fear of making mistakes and promoted active participation in idea generation. According to Syaflita et al. (2024), the ideation stage is closely associated with divergent thinking because it encourages fluency, flexibility, and originality in generating solutions. Likewise, Javaid and Pandarakalam (2021) emphasized that divergent thinking is fundamental to creativity because it enables individuals to explore multiple possibilities when addressing complex problems.

The improvement in flexibility further indicates that students became more capable of considering different perspectives and exploring alternative solution pathways. Inquiry-based learning encourages learners to examine evidence from multiple sources and revise their assumptions when new information emerges. When

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combined with design thinking, students are encouraged to compare alternatives, receive feedback, and modify their solutions iteratively. This process promotes cognitive flexibility, which is widely recognized as a key component of creative thinking (Luka, 2019).

The originality indicator also demonstrated a high gain, suggesting that students became increasingly capable of producing unique and innovative ideas. This finding may be attributed to the authentic and contextual nature of the learning activities. Rather than relying solely on textbook examples, students were challenged to analyze real-world issues related to circulatory system disorders and propose innovative solutions. Exposure to authentic problems often stimulates creative responses because students are required to move beyond memorized knowledge and generate ideas that address specific contexts (Lin & Chang, 2025).

Similarly, the substantial increase in elaboration demonstrates that students not only generated ideas but also refined and expanded them in greater detail. The prototype and test stages of design thinking played a significant role in this process by encouraging students to improve their initial ideas through discussion, feedback, and evaluation. Henriksen et al. (2017) argued that design thinking promotes creativity not only through idea generation but also through the refinement and elaboration of ideas.

Inquiry activities also contributed to creative thinking development by encouraging students to explore biological phenomena independently and construct explanations based on evidence. Rather than receiving information directly from teachers, students actively built knowledge through investigation and discussion. Such learning experiences provided opportunities for students to express unique ideas, question assumptions, and develop innovative solutions. Therefore, the integration of inquiry-based learning and design thinking created a learning environment that simultaneously promoted creativity and scientific reasoning (Syahrial et al., 2019; Marianingsih, 2025).

Overall, the findings indicate that inquiry-based learning based on design thinking is an effective instructional approach for improving both problem-solving ability and creative thinking skills. The significant multivariate effect identified through MANCOVA confirms that the integration of inquiry and design thinking supports the

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simultaneous development of higher-order thinking skills. Students who were capable of generating diverse and original ideas were also better equipped to formulate and implement effective solutions. Likewise, students with stronger problem-solving skills were more likely to engage in creative exploration when addressing biological problems. These findings support previous studies suggesting that inquiry and design thinking complement one another by fostering analytical reasoning, creativity, innovation, and solution-oriented thinking (Caldevilla-Domínguez et al., 2021; Thapa & Mishra, 2025).

From an educational perspective, the circulatory system is often considered a challenging topic because it involves interconnected concepts, physiological processes, and health-related issues that require both conceptual understanding and practical application (Ittikitpaisarn & Jittivadhna, 2025). Traditional instructional approaches that emphasize content delivery may provide limited opportunities for students to apply scientific knowledge in meaningful contexts. The present findings suggest that inquiry-based learning integrated with design thinking can help address this limitation by encouraging students to investigate authentic problems, construct scientific explanations, develop innovative solutions, and evaluate their effectiveness. These findings are consistent with Yu et al. (2024), whose meta-analysis demonstrated that design thinking had a positive overall effect on student learning, including problem-solving ability and creative thinking. Therefore, integrating inquiry-based learning with design thinking represents a promising instructional approach for promoting higher-order thinking skills and preparing students to address complex challenges in twenty-first-century learning.

CONCLUSION

This study concludes that inquiry-based learning integrated with design thinking significantly influenced students' problem-solving ability and creative thinking skills in learning the circulatory system, even after controlling for their initial abilities. The integration of inquiry and design thinking provides opportunities for students to investigate biological problems, construct evidence-based explanations, develop alternative solutions, and evaluate their ideas. This approach is particularly relevant to biology learning because it connects scientific concepts with contextual problems and encourages students to apply their knowledge creatively. Nevertheless, the findings should be interpreted within the context of the study, which involved Grade XI students

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learning the circulatory system at one senior high school. Future research should examine the effectiveness of this instructional model across different biology topics, educational levels, and school contexts. Further studies could also investigate its effects on other competencies, such as critical thinking, collaboration, and learning motivation, to provide a more comprehensive understanding of its potential contribution to biology education.

DECLARATION:

Phenomenon: Jurnal Pendidikan MIPA was selected as the target journal for the publication of our paper because this journal strives to promote the implementation of high-quality mathematics and science education at all educational levels, an objective that aligns with the aims and scope of this internationally reputable journal. We confirm that both authors have approved the manuscript for publication in your journal.

Availability of Data and Materials: The data supporting the study was classified according to the institutions' authorities; therefore, the participants only agreed to participate in the study based on anonymity, and a confidentiality agreement was reached. The data can therefore not be divulged to any third party without official permission granted from the institutions which can either be accepted or declined.

Competing interests: The authors declare that they have no conflicting interests in the publication of the paper in your journal.

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Declaration of Generative AI Use: During the preparation of this manuscript, the authors used ChatGPT, developed by OpenAI, to assist with translation, grammatical revision, and improvements to writing clarity. All AI-generated output was reviewed, verified, and edited by the authors to ensure accuracy and consistency with the research data and objectives. The authors take full responsibility for the content and scientific integrity of the final manuscript.

Authors' contributions: Krisdayani Harefa, Rusdi, Diana Vivanti Sigit contributed to this article by identifying the research problem, conducting interviews, distributing questionnaires to participants, and drafting the entire manuscript. Krisdayani Harefa, Rusdi, Diana Vivanti Sigit played a key role in overseeing the drafting process, performing final proofreading, editing the manuscript, and conducting data analysis.

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