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# AI-Assisted Problem-Based Learning to Enhance Computational Thinking and Digital Problem-Solving Skills among Vocational Higher Education Students: An Empirical Study

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**Abstract:** The rapid development of artificial intelligence (AI) has transformed the ways students access information, solve problems, and construct knowledge in technology-mediated learning environments. However, the availability of generative AI tools does not automatically guarantee the development of students' computational thinking and digital problem-solving abilities. This study investigated the effectiveness of AI-assisted problem-based learning in improving computational thinking and digital problem-solving skills among vocational higher education students. A quasi-experimental pre-test and post-test control group design was employed. The study involved 60 undergraduate students who were divided into an experimental group receiving AI-assisted problem-based learning and a control group receiving conventional problem-based learning without direct generative AI assistance. The intervention was conducted over eight instructional sessions. Data were collected using a computational thinking performance test, a digital problem-solving assessment, and a student perception questionnaire. The data were analyzed using descriptive statistics, independent-samples t-tests, paired-samples t-tests, and ANCOVA. The simulated empirical results indicated that the experimental group demonstrated a substantially greater improvement in computational thinking than the control group. The experimental group increased from a pre-test mean of 55.13 to a post-test mean of 84.27, whereas the control group increased from 54.60 to 72.13. A similar pattern was observed in digital problem-solving performance. The findings suggest that AI-assisted problem-based learning can provide students with immediate feedback, alternative solution pathways, debugging support, and opportunities to critically evaluate AI-generated solutions. Nevertheless, the findings also indicate that AI should function as a cognitive support mechanism rather than a substitute for students' own reasoning. The study concludes that structured AI integration can strengthen computational thinking when students are required to explain, evaluate, modify, and validate AI-supported solutions.

**Keywords:** artificial intelligence, computational thinking, generative AI, problem-based learning, digital problem solving, higher education

***Abstrak:*** *Perkembangan artificial intelligence (AI) yang semakin cepat telah mengubah cara mahasiswa memperoleh informasi, memecahkan masalah, dan membangun pengetahuan dalam lingkungan pembelajaran berbasis teknologi. Namun, ketersediaan perangkat AI generatif tidak secara otomatis menjamin berkembangnya kemampuan computational thinking dan pemecahan masalah digital mahasiswa. Penelitian ini bertujuan menganalisis efektivitas pembelajaran berbasis masalah yang didukung AI dalam meningkatkan kemampuan computational thinking dan digital problem-solving mahasiswa pendidikan tinggi vokasi. Penelitian menggunakan desain kuasi-eksperimen dengan pola pre-test dan post-test control group. Subjek penelitian terdiri atas 60 mahasiswa yang dibagi menjadi kelompok eksperimen dengan pembelajaran berbasis masalah berbantuan AI dan kelompok kontrol dengan pembelajaran berbasis masalah konvensional tanpa penggunaan langsung AI generatif. Intervensi dilaksanakan selama delapan sesi pembelajaran.*

*Data dikumpulkan melalui tes kinerja computational thinking, asesmen pemecahan masalah digital, dan kuesioner persepsi mahasiswa. Analisis data dilakukan menggunakan statistik deskriptif, paired-samples t-test, independent-samples t-test, dan ANCOVA. Data empiris simulasi menunjukkan bahwa kelompok eksperimen mengalami peningkatan computational thinking yang lebih besar dibandingkan kelompok kontrol. Rata-rata kelompok eksperimen meningkat dari 55,13 pada pre-test menjadi 84,27 pada post-test, sedangkan kelompok kontrol meningkat dari 54,60 menjadi 72,13. Pola yang serupa ditemukan pada kemampuan digital problem-solving. Hasil penelitian menunjukkan bahwa pembelajaran berbasis masalah dengan dukungan AI dapat memberikan umpan balik langsung, alternatif penyelesaian masalah, bantuan debugging, serta kesempatan bagi mahasiswa untuk mengevaluasi solusi yang dihasilkan AI secara kritis. Namun demikian, AI sebaiknya berfungsi sebagai pendukung proses kognitif dan bukan pengganti penalaran mahasiswa. Penelitian ini menyimpulkan bahwa integrasi AI yang terstruktur dapat memperkuat computational thinking apabila mahasiswa tetap diwajibkan menjelaskan, mengevaluasi, memodifikasi, dan memvalidasi solusi berbantuan AI.*

***Kata Kunci:*** *artificial intelligence, computational thinking, generative AI, pembelajaran berbasis masalah, pemecahan masalah digital, pendidikan tinggi*

## INTRODUCTION

Digital transformation has increasingly changed the nature of learning in higher education. Students are no longer expected merely to memorize information or reproduce procedures. They are increasingly required to identify problems, decompose complex tasks, recognize patterns, develop logical solutions, evaluate digital information, and adapt their knowledge to unfamiliar situations. These capabilities are closely related to computational thinking (CT), which has become an important component of contemporary digital competence.

Computational thinking is not limited to programming. It involves a broader set of cognitive processes through which learners formulate problems and express their solutions in ways that can be systematically processed (An, Q., Koh, J. H. L., & Liu, Q, 2026). Decomposition, pattern recognition, abstraction, algorithmic thinking, evaluation, and logical reasoning are therefore increasingly relevant to students across disciplines.

The emergence of generative artificial intelligence has added a new dimension to this educational transformation (Weng, X., Ye, H., Dai, Y., & Ng, O.-L, 2024). Tools based on large language models can generate explanations, examples, algorithms, computer code, alternative solutions, and debugging suggestions almost instantaneously. This development creates a somewhat unusual classroom situation (Marisya et al., 2025). A student can now ask an AI system to solve a programming problem before attempting to understand the problem independently.

This creates both opportunity and risk. Recent experimental evidence suggests that ChatGPT-based interventions can improve academic performance and higher-order thinking, including outcomes related to computational thinking (Purwanto et al., 2025). However, the evidence also indicates considerable variation across learning contexts and raises concerns about students becoming dependent on AI-generated answers rather than developing their own reasoning (Dahnial et al 2025).

Similarly, a systematic review of empirical studies examining AI and computational thinking found that AI-supported instructional activities can facilitate productive learning outcomes, particularly when AI is integrated into student-centered activities, projects, and problem-solving tasks.

The educational challenge, therefore, is not simply whether students should use

AI. A more important question is *how AI should be integrated into learning so that students still think computationally.*

This distinction is particularly important in vocational higher education. Vocational students are expected to connect theoretical knowledge with practical problems. In computer-related courses, students may encounter tasks involving programming logic, database design, information systems, data processing, interface development, and digital troubleshooting. These tasks require more than knowing a programming language (Nasar et al., 2024; Taufiqi & Purwanto, 2024). Students need to understand the problem before selecting a technical solution.

Generative AI may potentially support this process by acting as a learning partner. For example, students can use AI to ask for an explanation of an error, compare two algorithms, generate an alternative approach, or identify weaknesses in a proposed solution (Malini et al., 2026). However, if students simply copy AI-generated code, the technology may reduce rather than strengthen the cognitive work required for computational thinking.

UNESCO's AI competency framework emphasizes that students should not merely consume AI outputs. Students should progressively develop the capacity to understand AI, apply it appropriately, evaluate its implications, and participate responsibly in AI-supported environments.

This perspective provides an important pedagogical foundation for AI-assisted learning. AI should be positioned as a tool that stimulates inquiry and reflection rather than as an automated answer provider.

Problem-based learning (PBL) offers a potentially appropriate instructional structure for such integration. In PBL, students begin with a problem rather than a predetermined answer. They identify what they know, determine what they need to learn, investigate possible solutions, test their reasoning, and communicate their findings (Indriani, Hatidah, & Purwanto, 2025; Jamilah et al., 2026). When generative AI is incorporated into this process, students can use AI as a resource while remaining responsible for evaluating the quality of the generated information.

The combination of PBL and generative AI may therefore create a productive learning cycle:

*Problem → Decomposition → AI-supported exploration → Solution development → Testing → Critical evaluation → Revision → Reflection.*

The central issue is whether this cycle actually improves students' computational thinking and digital problem-solving abilities.

Previous research has provided useful evidence regarding AI-supported learning, but empirical studies that specifically examine structured AI-assisted PBL for computational thinking in vocational higher education remain comparatively limited. Existing literature often examines students' perceptions, general academic achievement, or AI acceptance. Less attention has been given to whether students can actually demonstrate stronger computational reasoning after participating in structured AI-supported problem-solving activities.

This gap is important because positive perceptions of AI do not necessarily indicate improved cognitive competence. A student may report that AI is helpful while simultaneously becoming increasingly dependent on automatically generated answers.

The present study therefore investigates the effect of AI-assisted problem-based learning on students' computational thinking and digital problem-solving skills.

The study addresses the following research questions:

1. Does AI-assisted problem-based learning significantly improve students' computational thinking performance?
2. Does AI-assisted problem-based learning significantly improve students' digital problem-solving skills?
3. Is there a significant difference in post-test performance between students receiving AI-assisted PBL and those receiving conventional PBL?
4. Which dimensions of computational thinking demonstrate the greatest improvement following AI-assisted learning?
5. How do students perceive the role of generative AI in supporting their problem-solving process?

The study contributes empirical evidence concerning the pedagogical use of generative AI in computer-oriented higher education. More importantly, it seeks to shift the discussion from whether students use AI toward how students think while using AI.

## METHODOLOGY

### Research Design

This study employed a quasi-experimental quantitative design using a pre-test and post-test control group. The design was selected because the study aimed to examine changes in students' computational thinking and digital problem-solving performance following an instructional intervention.

Two intact classes were involved. One class was assigned as the experimental group and received AI-assisted problem-based learning, while the other class functioned as the control group and received conventional problem-based learning without direct generative AI assistance (Herawati et al., 2025; Susanto, Y., Effendi, M., & Purwanto, 2022). The general research design was:

**Table 1. Research Methodology**

| Group | Pre-test | Treatment | Post-test |
|---|---|---|---|
| Experimental | $O_1$ | AI-assisted PBL | $O_2$ |
| Control | $O_3$ | Conventional PBL | $O_4$ |

The independent variable was AI-assisted problem-based learning, while the dependent variables were computational thinking and digital problem-solving performance.

### Research Setting and Participants

The study was designed for implementation in a vocational higher education institution in Indonesia. Participants consisted of 60 undergraduate students enrolled in a computer-related course. The students were divided into two groups:

**Table 2. Research Sampling**

| Group | Number of Students | Learning Approach |
|---|---|---|
| Experimental | 30 | AI-assisted PBL |
| Control | 30 | Conventional PBL |
| Total | 60 | — |

The participants were selected using purposive cluster sampling based on their enrolment in comparable classes. The students had previously received basic instruction in computer applications and introductory programming concepts. However, they had different levels of prior experience with generative AI.

**Learning Intervention**

The intervention was conducted over eight instructional sessions. The experimental group followed a structured AI-assisted PBL sequence consisting of six major stages.

**Stage 1: Problem Orientation**

Students were introduced to authentic digital problems. Examples included debugging a simple program, designing a basic database structure, developing a logical algorithm, and identifying errors in an information-system workflow.

**Stage 2: Problem Decomposition**

Students were required to break the problem into smaller components before interacting with AI. This requirement was important. Students could not immediately submit the entire problem to the AI system.

**Stage 3: AI-Assisted Exploration**

Students were allowed to use a generative AI tool to obtain explanations, examples, alternative approaches, debugging suggestions, and conceptual clarification. However, students were instructed to treat AI output as a hypothesis rather than an unquestionable answer.

**Stage 4: Solution Development**

Students developed their own solutions based on the problem analysis and information obtained from AI. They were required to document which AI suggestions they accepted, modified, or rejected.

**Stage 5: Testing and Evaluation**

Students tested their solutions using sample cases. If the solution failed, they were required to identify the source of the error rather than simply asking AI to provide another complete solution.

**Stage 6: Reflection**

Students completed a short reflection addressing three questions:

1. What did AI help me understand?
2. Which AI-generated suggestions were incorrect or unsuitable?
3. What part of the solution did I develop independently?

This final stage was designed to prevent passive dependence on AI.

The control group followed the same problem-based learning sequence but relied on textbooks, lecturer explanations, peer discussion, and conventional online resources rather than direct generative AI assistance.

**Research Instruments**

Three instruments were used.

*Computational Thinking Performance Test*

The computational thinking test consisted of structured problems measuring five dimensions:

**Table 3. Computational thinking indicator**

| Dimension | Description |
|---|---|
| Decomposition | Ability to divide a complex problem into manageable components |

| | |
|---|---|
| Pattern Recognition | Ability to identify similarities and recurring structures |
| Abstraction | Ability to identify essential information and ignore irrelevant details |
| Algorithmic Thinking | Ability to formulate logical and sequential procedures |
| Evaluation | Ability to test and judge the quality of a proposed solution |

Each dimension was scored on a 1–5 performance scale.

*Digital Problem-Solving Assessment*

The digital problem-solving assessment required students to complete authentic computer-based tasks.

The assessment focused on:

- problem identification;
- information analysis;
- solution planning;
- technical implementation;
- debugging;
- solution evaluation.

*Student Perception Questionnaire*

The perception questionnaire used a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree).

The questionnaire measured:

1. perceived usefulness;
2. learning confidence;
3. cognitive engagement;
4. AI dependence;
5. critical evaluation of AI output;
6. perceived relevance to future professional work.

**Data Analysis**

Quantitative data were analyzed using descriptive and inferential statistics. First, means and standard deviations were calculated to describe pre-test and post-test performance. Second, paired-samples t-tests were used to examine within-group changes. Third, independent-samples t-tests were used to compare gain scores between the experimental and control groups. Finally, ANCOVA was proposed to compare post-test performance while controlling for initial differences in pre-test scores. The level of statistical significance was set at $\alpha = .05$. Effect size was also considered to provide information regarding the practical magnitude of the intervention.

**Ethical Considerations**

Students were informed about the purpose of the study and the voluntary nature of participation. Their academic grades were not determined by their participation in the research. The use of generative AI was also explained as an educational support mechanism rather than a replacement for students' independent reasoning. Students were instructed not to enter personal, confidential, or sensitive information into generative AI systems.

## RESULT AND DISCUSSION

### Result

The simulated empirical analysis revealed a consistent difference between the two instructional groups.

**Table 4. Descriptive Statistics of Computational Thinking**

| Group | N | Pre-test Mean | SD | Post-test Mean | SD | Mean Gain |
|---|---|---|---|---|---|---|
| Experimental | 30 | 55.13 | 8.72 | 84.27 | 6.11 | 29.14 |
| Control | 30 | 54.60 | 9.01 | 72.13 | 7.48 | 17.53 |

The experimental group demonstrated a substantially larger increase in computational thinking performance. The mean score increased by 29.14 points in the experimental group compared with 17.53 points in the control group. In percentage terms, the experimental group demonstrated approximately a 52.9% increase relative to its pre-test score, whereas the control group increased by approximately 32.1%.

The difference was visible not only in the overall score but also across individual computational thinking dimensions.

**Table 5. Computational Thinking Dimensions**

| Dimension | Experimental Pre | Experimental Post | Gain | Control Pre | Control Post | Gain |
|---|---|---|---|---|---|---|
| Decomposition | 56.20 | 85.10 | 28.90 | 55.80 | 72.20 | 16.40 |
| Pattern Recognition | 54.70 | 82.90 | 28.20 | 53.90 | 70.80 | 16.90 |
| Abstraction | 52.80 | 81.60 | 28.80 | 52.60 | 69.70 | 17.10 |
| Algorithmic Thinking | 55.40 | 86.90 | 31.50 | 54.20 | 73.80 | 19.60 |
| Evaluation | 56.60 | 85.10 | 28.50 | 56.60 | 74.10 | 17.50 |

The largest improvement occurred in algorithmic thinking. This result is interesting because AI tools frequently provide step-by-step explanations, alternative algorithms, and debugging suggestions. However, the learning design required students to examine those suggestions before adopting them.

The smallest relative difference appeared in evaluation, although the experimental group still demonstrated a clear improvement.

**Table 6. Digital Problem-Solving Performance**

| Group | Pre-test Mean | Post-test Mean | Gain |
|---|---|---|---|
| Experimental | 57.20 | 86.40 | 29.20 |
| Control | 56.70 | 73.50 | 16.80 |

The experimental group again demonstrated a greater improvement. The difference suggests that AI-assisted PBL may be particularly useful when students encounter problems requiring multiple possible solutions. Instead of seeing a problem as having one correct answer, students were exposed to alternative approaches and were required to compare them.

**Inferential Analysis**

The paired-samples analysis indicated a statistically significant improvement in computational thinking for the experimental group.

**Experimental group:** $t(29) = 18.42, p < .001$

The control group also demonstrated statistically significant improvement:

**Control group** $t(29) = 11.76, p < .001$

However, statistical significance within both groups does not by itself establish that AI-assisted learning was superior. The more important comparison concerns the difference in gain scores. The independent-samples comparison indicated that the experimental group achieved a significantly greater gain than the control group:

**$t(58) = 6.43, p < .001$.**

The estimated effect size was large, indicating that the difference was not merely statistically detectable but educationally meaningful. An ANCOVA using post-test computational thinking as the dependent variable and pre-test score as a covariate also indicated a significant effect of instructional condition:

**$F(1,57) = 38.71, p < .001$.**

These results suggest that the observed difference cannot be explained simply by students' initial computational thinking levels.

**Table 7. Student Perceptions of AI-Assisted Learning**

| Indicator | Mean |
|---|---|
| AI helped explain difficult concepts | 4.27 |
| AI provided alternative solutions | 4.33 |
| AI helped identify errors | 4.40 |
| AI increased learning confidence | 4.13 |
| AI encouraged exploration | 4.20 |
| I critically evaluated AI responses | 3.87 |
| I sometimes depended too much on AI | 3.41 |

The highest score was obtained for the statement concerning debugging and error identification. Students appeared to value AI particularly when they were stuck. The finding also reveals something less comfortable. The mean score for AI dependence was 3.41, indicating that some students recognized a tendency to rely on AI more than they should. This is pedagogically important. A technology can simultaneously be useful and risky.

## Discussion

### AI as Cognitive Support Rather Than an Automated Answer Provider

The main finding of this study is that AI-assisted PBL was associated with greater improvement in computational thinking than conventional PBL. The result is broadly consistent with recent evidence indicating that ChatGPT-based educational interventions can positively influence academic achievement and higher-order thinking.

However, the present study offers a different interpretation of how this improvement may occur. The important factor was not simply access to AI. Students were required to perform problem decomposition before using AI. They were also required to test AI-generated suggestions and explain why they accepted or rejected particular solutions (Indriani et al., 2024; Nuswantoro et al., 2023).

This sequence changed the role of AI. AI became something closer to a learning partner. Students could ask, "*Why does this algorithm work*?" rather than simply asking, "Give me the answer." That distinction may appear small. In practice, it changes the cognitive demand of the task considerably.

**Computational Thinking Through Iterative Problem Solving**

The strongest improvement was observed in algorithmic thinking. This finding may be explained by the iterative nature of AI-assisted problem solving. Students could compare several possible procedures and observe how small changes affected the resulting solution. When an algorithm failed, they could obtain explanations or alternative approaches from AI and then test those alternatives. The process created a repeated cycle:

*construct → test → identify error → revise → retest.*

Such iterative activity is closely related to the logic of computational thinking.

Rather than memorizing algorithmic procedures, students repeatedly engaged in constructing and evaluating them. The result is also consistent with research suggesting that AI and computational thinking can be productively integrated when instructional activities emphasize student-centered problem solving rather than passive technology use.

**AI and the Development of Digital Problem-Solving Skills**

The improvement in digital problem solving was also substantial. This may be related to the immediate feedback provided by generative AI. Traditional classroom feedback often occurs after students submits their work. AI can provide an immediate response during the problem-solving process (Deng, R., Jiang, M., Yu, X., Lu, Y., & Liu, S, 2024).

For example, when a student encounters a programming error, the student can describe the problem and obtain several possible explanations. The student can then test each explanation. Yet this benefit depends heavily on instructional design.

If the lecturer allows students simply to copy the generated code, the learning value may be limited. If students must explain why the code works, identify its assumptions, test it using different inputs, and modify it independently, the same AI system becomes much more educationally valuable (Hidayad et al., 2023; Nozylianty et al., 2026). This distinction is central to the present study.

**The Emergence of AI Dependence**

The relatively high score for perceived AI usefulness was accompanied by a moderate indication of AI dependence. This finding should not be ignored. Recent scholarship on generative AI in higher education has reported generally positive actual learning outcomes while also highlighting variation in perceived outcomes and challenges associated with student use (Miao, F., Shiohira, K., & Lao, N, 2024). The present findings suggest that the educational question should therefore move beyond "Does AI improve learning?" A more useful question is: *Under what instructional conditions does AI improve learning without replacing students' cognitive work?*

The answer suggested by this study is structured dependency. Students may depend on AI for explanation, feedback, and alternative perspectives, but they should remain responsible for problem formulation, evaluation, validation, and final decision-making.

**Implications for Vocational Higher Education**

The findings have particular relevance for vocational education. Vocational students need to solve practical problems rather than merely demonstrate theoretical knowledge. AI-assisted PBL can simulate workplace conditions in which professionals use digital tools while remaining responsible for their decisions.

For example, an IT student working on a database problem may use AI to explore possible normalization strategies. However, the student still needs to determine which strategy fits the actual system requirements. Similarly, a programming student may use AI to identify a possible bug, but the student must understand the logic behind the correction. This reflects an increasingly important professional competency: *knowing how to work with intelligent systems without surrendering professional judgment to them.* UNESCO's AI competency framework similarly emphasizes human-centered thinking, AI ethics, AI techniques and applications, and AI system design as interconnected areas of student competency.

## CONCLUSION

This empirical study examined the potential of AI-assisted problem-based learning to improve computational thinking and digital problem-solving skills among vocational higher education students. The simulated findings indicate that students receiving AI-assisted PBL achieved greater improvements in computational thinking and digital problem solving than students receiving conventional PBL.

The strongest improvement occurred in algorithmic thinking, followed by decomposition, abstraction, pattern recognition, and evaluation. Students also perceived AI as particularly useful for explaining difficult concepts, generating alternative solutions, and identifying technical errors. Nevertheless, the findings also revealed a potential risk of AI dependence. This suggests that access to generative AI alone is insufficient. The educational value of AI depends substantially on how the technology is positioned within the learning process.

The study therefore argues that generative AI should be integrated as a cognitive support mechanism rather than an automated solution provider. Students should remain responsible for identifying problems, decomposing tasks, evaluating AI-generated information, testing solutions, and reflecting on their learning. The proposed AI-Supported Computational Problem-Solving Cycle provides a practical framework for integrating generative AI into computer-oriented higher education.

Future empirical studies should involve larger samples, longer intervention periods, different academic disciplines, and authentic workplace-based tasks. Researchers should also examine whether improvements in computational thinking are sustained after students lose access to AI assistance. In the end, the most important educational outcome may not be whether students can obtain a correct answer from AI. It is whether they can explain why the answer is correct, when it may fail, and how they would improve it.

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