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ORIGINAL

AI-PBL Framework: Innovative Problem Based Learning Model Supported by Artificial Intelligence Technology

Marco AI-PBL: Modelo Innovador De Aprendizaje Basado En Problemas Con Tecnología De Inteligencia Artificial

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ABSTRACT

Introduction: this study aims to develop a Problem-Based Learning (PBL) framework integrated with Artificial Intelligence (AI) technology to enhance the critical thinking skills of students in the Mechanical Engineering Study Program at Padang State University (UNP).
Method: a developmental research methodology based on the ADDIE framework was implemented in this study. The subjects involved were students enrolled in the Mechanical Engineering Department at UNP.
Results: validation results from seven experts indicated that the developed product falls into the valid category. In addition, the practicality test involving two lecturers and ten students yielded a score of 80,99 %, placing it in the "highly practical" category. Regarding effectiveness, the t-test produced a value of 0,000, which is less than 0,05, indicating a statistically significant difference between the experimental and control groups.
Conclusion: based on the findings from the validation, practicality, and effectiveness assessments, the AI-supported PBL model is considered valid, highly practical, and effective in enhancing the critical thinking abilities of Mechanical Engineering students at UNP.

Keywords: Model Development; Problem Based Learning; Artificial Intelligent; ADDIE.

RESUMEN

Introducción: este estudio tiene como objetivo desarrollar un marco de aprendizaje basado en problemas (PBL) integrado con tecnología de inteligencia artificial (IA) para mejorar las habilidades de pensamiento crítico de los estudiantes en el Programa de Estudios de Ingeniería Mecánica en la Universidad Estatal de Padang (UNP).
Método: se implementó una metodología de investigación de desarrollo basada en el marco ADDIE. Los participantes fueron estudiantes del Departamento de Ingeniería Mecánica de la UNP.
Resultados: la validación realizada por siete expertos indicó que el producto desarrollado se encuentra en la categoría de válido. Además, la prueba práctica, con dos profesores y diez estudiantes, arrojó una puntuación del 80,99 %, lo que lo sitúa en la categoría de "altamente práctico". En cuanto a la efectividad, la prueba t arrojó un valor de 0,000, inferior a 0,05, lo que indica una diferencia estadísticamente significativa entre los grupos experimental y de control.
Conclusión: con base en los hallazgos de las evaluaciones de validación, practicidad y eficacia, el modelo de aprendizaje basado en problemas (ABP) con apoyo de IA se considera válido, altamente práctico y eficaz para fortalecer el pensamiento crítico de los estudiantes de Ingeniería Mecánica de la UNP.

Palabras clave: Desarrollo de Modelos; Aprendizaje Basado en Problemas; Inteligencia Artificial; ADDIE.

INTRODUCTION

The higher education system plays a crucial role in facilitating effective student learning and in shaping graduates who are well-prepared and competent.[1,2,3] To improve the competitiveness of the Indonesian nation in facing globalization in all fields, it is necessary to develop science and technology.[4] Lecturers have an important role in providing quality education services.[5] Higher Education requires students to develop a number of skills and attitudes (Softskill and Hardskill) needed in the dynamic and global world of work and students must have global and broad thinking.[6,7,8] Students must be able to compete in this ever-changing world. Students must be able to develop critical thinking skills, creative, communicative, collaborative, able to use technology, critical thinking, and adaptive.[9,10] Soft skills in the form of Critical Thinking are the main goal to make students able to face the development of today's world.[11] The development of the world today is increasing as the complexity and dynamics of the world continue to change.[12]

Based on observations and the results of preliminary analysis conducted on Mechanical Education students at the Faculty of Engineering, Padang State University (UNP), students still lack the skills they have. For example, the way of thinking that has not been creative and critical (Critical Thinking). This can be seen when they answer questions or problems given not yet at the analysis and evaluation stage. They have not been able to analyze and develop the results of their thinking. As a result, they find it difficult to solve the problems given and learning outcomes are low.

Student learning outcomes can be improved through increasing student Critical Thinking. Critical thinking represents one of the advanced cognitive abilities, alongside skills such as creative thinking, reflective analysis, and effective problem-solving.[13] As students' critical thinking skills improve, their academic performance also shows significant progress. Numerous experts have explored this relationship through a variety of research efforts. Some use applications in the learning process,[14] using a practicum-based guided method,[15] doing collaborative work in groups,[16] and use a learning model in the form of PBL in learning.[17,18]

Problem Based Learning (PBL) not only improves students' critical thinking, but also has an impact on student learning outcomes.[19,20] PBL engages students in an active, cooperative, and student-focused learning process.[21] PBL initiates the learning process by posing a problem, then proceeds with organizing learning tasks, guiding students through investigation, encouraging them to present their results, and ending with reflection and evaluation of how the problem was addressed. A defining trait of PBL is the use of problems as the starting point for learning.[22] PBL is an instructional approach that enhances students' participation in learning and encourages them to articulate their thoughts more effectively.[23] The characteristics of PBL are proposing problems, looking for knowledge linkages, conducting investigations, producing products, presenting them, and group discussions.[24] PBL is learner-centered learning that guides students in group learning.[25] PBL implementation steps are problem orientation, group division, group discussion, presentation of discussion results, evaluation of discussion results.[26] Through a student-focused framework, PBL motivates students to become more involved, imaginative, and inventive, making the educational experience more self-directed, relevant, and enjoyable.[27,28] PBL is also able to improve and stimulate students' critical thinking.[29] Therefore, PBL supports the development of students' thinking abilities in addressing and resolving problems.

Improving students' critical thinking has been done through previous studies as explained above. Here, researchers try to make innovations in improving student critical thinking. That is, through the development of an AI-based PBL model in improving student critical thinking, namely for students in the UNP Mechanical Engineering department. The innovation that researchers do is to use various AI technologies in developing PBL models. The goal is to maximize the guidance of students' thinking skills and so that students do not miss digitalization technology. The utilization of AI technology can increase the ability of human creativity in thinking and facing the times.[30] There are so many technologies that apply AI in everyday life. The AI technologies that will be used are Chatgpt, Perplexity AI, Claude AI, Gemini AI. AI technology makes it easier to find the information needed by students and provides novelty in today's world of technology.[31] ChatGPT, for example, can also improve students' critical thinking in the learning process.[32]

To prepare students for a rapidly evolving era and to ensure their competitiveness in the face of global challenges across various sectors, it is essential to strengthen 21st-century skills—particularly critical thinking. Critical thinking is a core competency that enables students to analyze, evaluate, and solve complex problems effectively. Although numerous approaches have been implemented to foster students' critical thinking skills, challenges remain in aligning these methods with the current pace of technological advancement. This study, therefore, aims to develop a Problem Based Learning (PBL) model integrated with Artificial Intelligence (AI) as a strategic innovation to enhance the critical thinking abilities of Mechanical Engineering students at Padang State University (UNP).

METHOD

This research is conducted in the context of developing an innovative AI-based learning model in higher education, specifically aimed at enhancing the critical thinking skills of Mechanical Engineering students at Padang State University (UNP). The study follows a research and development approach and is tested in a classroom setting using a quasi-experimental design. The trial subjects in this study are planned to include two classes of students enrolled in the *Machining Process Technology* course. The independent variable or treatment applied to the experimental group is the Artificial Intelligence (AI)-based Problem-Based Learning (PBL) model. The dependent variable, which will be measured to determine the effectiveness of the developed model, is the students' critical thinking ability, assessed through pretests and posttests.

The instrument is a questionnaire used to conduct a needs analysis to measure the critical thinking of Mechanical Engineering students at Padang State University. Questionnaires about student critical thinking are based on theoretical studies and the suitability of items with the conditions to be revealed. As for validation, and the practicality of the model will be prepared separate instruments. The research sample was UNP Mechanical Engineering students. The type of data taken from the validation test results on model construction, model content, RPKPS & SAP, learning modules, lecturer guidebooks, student guidebooks, and instruments in model development. Assessment or validation conducted by a team of validators of the AI-based PBL Model in the Machining Process Technology Course. The data collected during the trial phase includes the results of practicality evaluations conducted by both lecturers and students. The research stages are illustrated in figure 1 below.

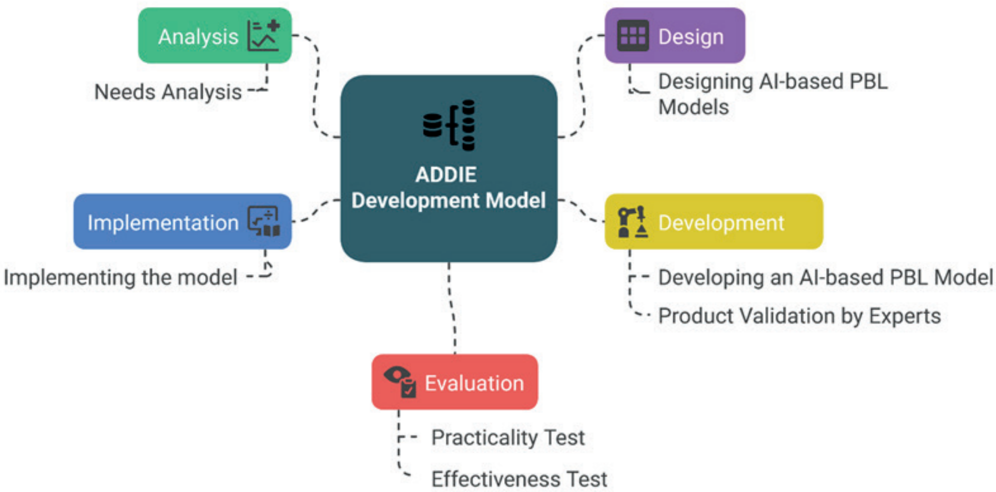

Figure 1. Research Flow of ADDIE Development Model for AI Based PBL

First, the analysis stage involves conducting a needs analysis and curriculum analysis to assess the critical thinking skills of Mechanical Engineering students at Padang State University (UNP), as well as reviewing previous studies related to model development. Second, the design stage focuses on formulating a learning model based on the results of the previous analysis, with the aim of strengthening students' critical thinking skills in a classroom setting. The next stage, development, involves constructing a PBL model integrated with AI technology, refined based on expert input to better foster critical thinking. This stage includes validation by seven experts. The validation process covers the model's construction, content, course outline (RPKPS), lesson plans (SAP), learning modules, lecturer's guidebook, student's guidebook, and model development instruments. Data collection is carried out using a Likert scale with five response categories ranging from 1 (strongly not representative or highly irrelevant) to 5 (strongly representative or highly relevant). The data collected are analyzed using Aiken's V technique, followed by revisions based on expert feedback. The implementation stage involves applying the developed learning model in the classroom for Mechanical Engineering students at UNP. Lastly, the evaluation stage assesses the model's practicality and effectiveness. Practicality is evaluated by having two lecturers and ten students complete a questionnaire after the implementation of the developed model, with data analyzed using percentage-based techniques. Meanwhile, the model's effectiveness is assessed through students' learning outcomes, which are analyzed using a t-test. Evaluation instruments designed by considering High Order Thinking Skills (HOTS) questions at cognitive level C4 and above.

DEVELOPMENT

The PBL-AI model is a refinement of the AI-enhanced PBL framework intended for implementation within the learning sequence. This model consists of seven instructional steps, which are presented in figure 2 below.

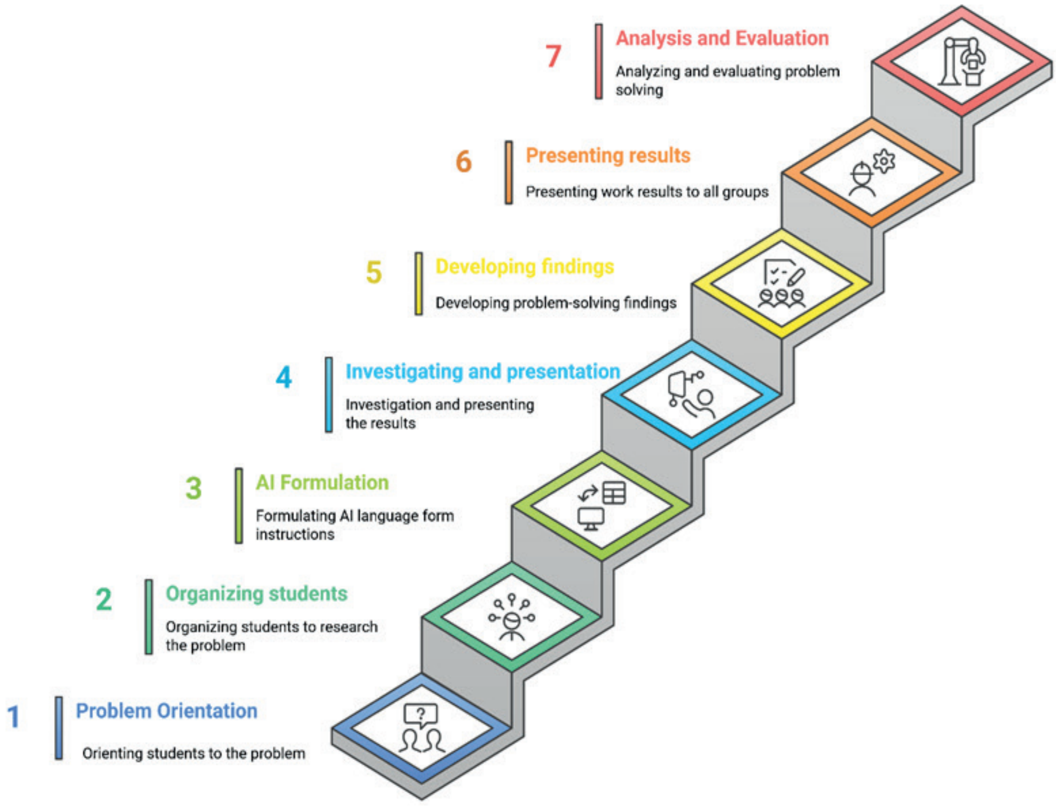

Figure 2. Syntax of AI-based PBL Model Development

According to figure 2, the PBL-AI model follows seven stages in its learning structure: (1) Introducing the problem to students, (2) Organizing learners to examine the issue, (3) Designing AI-based instructions through learner-AI communication, (4) Individual exploration and sharing results in peer groups, (5) Refining group solutions based on collective AI-guided inquiry, (6) Presenting outcomes in a class-wide discussion, and (7) Analyzing and reviewing the approach used to address the problem. Following the development of this model, the AI-based PBL model was tested for validity, practicality, and effectiveness to ensure that it can be successfully implemented in the learning process.

RESULTS

The first phase in the development research of an AI-based PBL model aimed at enhancing the critical thinking skills of Mechanical Engineering students at Padang State University is the Analysis phase. During this stage, various activities are conducted, including a needs analysis and curriculum analysis. The needs analysis encompasses several tasks, such as identifying field-related issues, reviewing relevant literature, examining the research context and environment, defining the research focus, and collecting preliminary data through interviews and observations to assess needs and existing challenges. Additional analyses are also carried out to ensure all necessary aspects are addressed.

The second phase is the Design stage. This involves setting specific, measurable learning objectives, selecting instructional strategies aligned with PBL principles, and planning the integration of artificial intelligence to enhance each phase of the learning process. Based on the findings from the analysis phase, a learning model is formulated to improve the critical thinking abilities of Mechanical Engineering students at UNP. In this stage, the researchers designed the AI-based PBL model by establishing clearly defined and structured learning steps that integrate AI tools effectively.

The development of the AI-based PBL model book involved integrating and modifying the syntax of both the traditional PBL model and AI components, resulting in a new set of instructional steps tailored for the AI-based PBL learning model, which consists of seven distinct stages. The design of the lecturer's guidebook using the AI-based PBL model is as a lecturer's handbook in the learning process so that the applied model can be implemented properly. The lecturer's guidebook using the AI-based PBL model is expected that lecturers can apply AI-based PBL syntax in class learning activities. In addition, the student handbook designed for the AI-based PBL model serves as a learning companion to ensure the effective implementation of the instructional approach. And the design of teaching modules in the machining process technology course is a learning resource used by students later in learning activities.

The third step is Development. This stage focuses on making and initial testing in the form of model prototype development and expert validation. In developing the prototype model, researchers developed AI-based PBL modules or scenarios and made prototypes of devices and media used in learning. For expert validation, involving 7 experts in education, technology, and mechanical engineering to evaluate the models and media developed and make revisions based on input from experts. Validation is carried out on the construction of the development model, model content, RPKPS & SAP, learning modules, lecturer guidebooks, student guidebooks, and model instruments. The outcomes of the validation process are presented in table 1 below.

Table 1. Validity Results

No	Validated Aspects	Aiken's V	Information
1.	Construction of Problem Based Learning Model Based on Artificial Intelligence	0,832	Valid
2.	Contents of the Problem Based Learning Model Based on Artificial Intelligence	0,838	Valid
3.	RPKPS and SAP Model Problem Based Learning Based on Artificial Intelligence	0,824	Valid
4.	Machining Process Technology Module in the Development of Artificial Intelligence-Based Problem Based Learning Models	0,828	Valid
5.	Lecturer's Guidebook	0,843	Valid
6.	Student Handbook	0,837	Valid
7.	Model instrument	0,848	Valid

Based on table 1 above regarding the results of the validity test using the Aiken's V formula on the validated aspects, namely in the form of model construction, model content, RPKPS & SAP, learning modules, lecturer guidebooks, student guidebooks and model instruments. The validation procedure was conducted to ensure that the developed Artificial Intelligence (AI)-based Problem-Based Learning (PBL) instructional model is both theoretically and practically feasible before being implemented in the learning process. This validation encompassed several components, including the model construction, model content, Semester Learning Plan (RPKPS), Lecture Implementation Plan (SAP), learning modules, lecturer's guidebook, student handbook, and critical thinking assessment instruments. The instrument used in the validation process was a rating questionnaire designed in the form of a Likert scale with five categories: 1 (strongly unrepresentative/ highly irrelevant), 2 (unrepresentative/irrelevant), 3 (moderately representative/moderately relevant), 4 (representative/relevant), and 5 (strongly representative/highly relevant). Each item in the questionnaire was constructed to reflect the quality and relevance of the model components to the development of mechanical engineering students' critical thinking skills. The validation was carried out by seven experts with relevant competencies and experience in their respective fields. These experts included: (1) a technical education specialist, (2) a learning model development expert, (3) an educational technology expert specializing in Artificial Intelligence (AI), (4) an instructional evaluation expert, and (5) senior lecturers experienced in the implementation of PBL and technology-based learning. The experts were selected purposively to ensure the credibility and validity of the feedback provided. Data obtained from the expert evaluations were analyzed using Aiken's V technique, which is used to measure the content validity of each item in the instrument. The Aiken's V value was calculated for each item, with a value of $V \geq 0,80$ indicating a high level of validity and that the item is deemed appropriate. Conversely, items with a V value $< 0,80$ were revised based on expert feedback. Revisions were made systematically to refine the model, ensuring it is suitable for implementation in the learning context of Mechanical Engineering students at Universitas Negeri Padang (UNP). So from the results of expert validation of model construction, model content, RPKPS & SAP, learning modules, lecturer guidebooks, student guidebooks, and model instruments in the development of AI-Based PBL Models in Machining Process Technology Courses can be stated in the valid category.

The fourth step is Implementation in the form of applying the model on a larger scale. The model was implemented by applying the AI-based PBL syntax in learning activities involving Mechanical Engineering students, monitoring and observing the course of learning to identify the success of implementation and problems that arise, and collecting evaluation data through the use of instruments that have been designed to measure the achievement of goals, especially increasing students' critical thinking. At this stage, learning is carried out according to the syntax of the development of the AI-based PBL model.

Finally, the fifth step is Evaluation. At this stage, an evaluation of the results and development process is carried out as well as assessing the practicality and effectiveness. To assess the practicality of the developed AI-integrated Problem-Based Learning (PBL) model, two subject-matter experts teaching the *Machining Process Technology* course were asked to complete a structured questionnaire. The graphical summary of their evaluations is presented in figure 3 below.

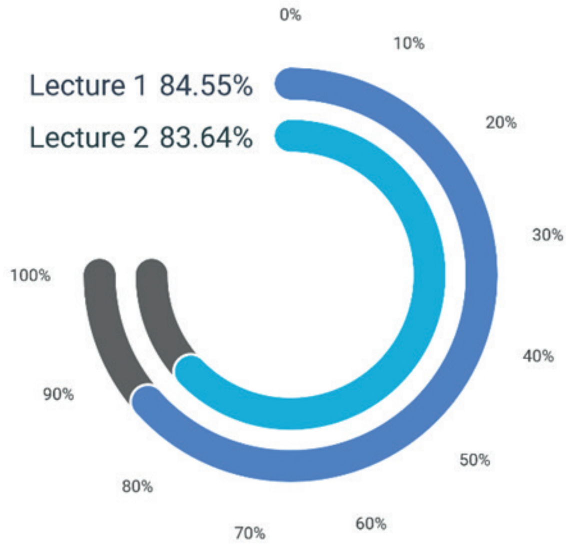

Figure 3. Lecture Practicality Score

As shown in figure 3, the two lecturers rated the practicality at 84,55 % and 83,64 % respectively, which were obtained through data processing using the percentage technique. Where between the assessments of the two lecturers was not much different in value, which if converted the value was declared the product was very practical. The findings from this evaluation indicate that the AI-integrated PBL model demonstrates a high level of practicality in the Machining Process Technology course.

Furthermore, the practicality test of the AI-based PBL model through student responses in the Machining Process Technology course was ten people. UNP Mechanical Engineering students were asked for their opinions about the practicality of the AI-based PBL model. The practicality test outcomes are presented through a questionnaire designed to evaluate the practicality of the developed AI-based PBL model. Student response data from this test is illustrated in the graph shown in figure 4 below.

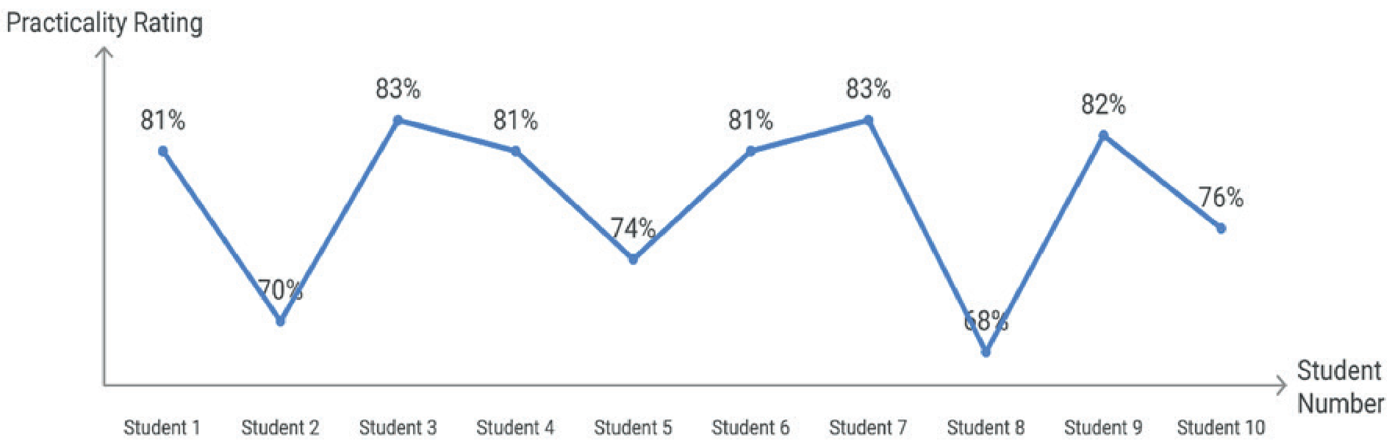

Figure 4. Student Practicality Ratings

Based on figure 4 above, the practicality assessment of the developed Artificial Intelligence (AI)-based Problem-Based Learning (PBL) model was conducted by distributing a structured questionnaire to ten undergraduate students who had engaged with the model during instructional activities. The questionnaire was constructed based on key indicators of practicality, including clarity of instructions, ease of use, time efficiency, and relevance to learning objectives. Each item was rated using a 5-point Likert scale ranging from *strongly disagree* to *strongly agree*. The collected data were analyzed using a percentage-based technique. The results are visualized in figure 4, showing the practicality scores of each student. The ratings varied, with the highest scores of 83 % recorded by Student 3 and Student 7, and the lowest score of 68 % by Student 8. Most students rated the model above 75 %, indicating that the AI-integrated PBL model was generally perceived as practical, effective, and easy to implement in the learning process. These findings suggest that the model has a high degree of practical applicability in real classroom settings, with minor variations likely attributable to individual differences in experience or familiarity with AI-based learning environments.

The effectiveness evaluation was conducted by analyzing student learning outcomes based on the final test scores from both the experimental and control groups. This assessment took place after the completion of the learning sessions in both classes. The post-test aimed to measure the impact of the developed learning program on student performance. In the experimental group, students were exposed to the AI-based PBL model, whereas the control group followed a conventional instructional method. Following the treatment, both groups underwent a post-test to evaluate their competencies. A comparison of the post-test results between the two groups is displayed in table 2 below.

Table 2. T-test of Post Test Values of Control and Experiment Classes

Independent Samples Test		t-test for Equality of Means				
		Sig. (2-tailed)	Mean Difference	Std. Error Difference	95 % Confidence Interval of the Difference	
					Lower	Upper
Hasil Belajar	Equal variances assumed	0,000	-10,621	1,431	-13,535	-7,707
	Equal variances not assumed	0,000	-10,621	1,440	-13,564	-7,678

As shown in table 2, the t-test analysis of the post-test scores from both groups, conducted using the SPSS software, produced a significance level of 0,000, which is less than 0,05. This result suggests that there is a notable difference in student learning outcomes between the control and experimental classes at the conclusion of the course. Therefore, it can be inferred that the difference between the two groups is statistically significant. The t-test findings confirm that the instructional strategy implemented in the experimental class yields different results compared to the traditional method used in the control class.

DISCUSSION

This study seeks to design an AI-supported PBL model to enhance the critical thinking abilities of Mechanical Engineering students at UNP. Within the educational context, critical thinking is a fundamental skill for addressing intricate technical challenges. The research integrates AI with the PBL approach to develop an innovative learning framework that is interactive, adaptive, and rooted in real-world problems. The development process follows the ADDIE model, which consists of five key phases: Analysis, Design, Development, Implementation, and Evaluation. During the analysis phase, the focus was on identifying instructional needs and student characteristics. The design phase involved structuring the PBL model to align with AI functionalities in the learning process. In the development phase, various instructional tools were created, including model construction, content materials, lesson plans (RPKPS & SAP), learning modules, instructor manuals, student handbooks, and assessment instruments. These tools were then systematically implemented and evaluated.

The validity test was carried out at the development stage involving 7 experts in education, technology, and mechanical engineering to evaluate the models and media developed and make revisions based on input from experts. The results of the validity test on model construction, model content, RPKPS & SAP, learning modules, lecturer guidebooks, student guidebooks and model instruments, obtained results of 0,832, 0,838, 0,824, 0,828, 0,843, 0,837, 0,848. If the results of this validity test are averaged, the Aiken's value> 0,600 is obtained and then interpreted and has a high enough coefficient.[33] From the results of expert validation of model construction, model content, RPKPS & SAP, learning modules, lecturer guidebooks, student guidebooks, and model instruments in the development of AI-Based PBL Models in Machining Process Technology Courses can be declared in the valid category and can be used for the next step.

After the developed product is valid, this product can be implemented in learning to UNP Mechanical Engineering students. Furthermore, the practicality test was carried out to find out how easy, feasible, and practical the product was used by users. This practicality test was conducted on a small scale by two lecturers and 10 student responses. From the practicality results, the practicality results from two lecturers were 84,09 % with a very practical category and from the average student response of 77,90 %. If this practicality value is averaged, a value of 80,99 % is obtained. Based on the analysis of practicality ratings, the product is classified as having a high level of practicality.[34]

Furthermore, these findings align with Judith,[35] who emphasized that ensuring validity from the initial design phase is crucial in educational development research to prevent discrepancies between model structure and pedagogical objectives. The high validity scores obtained in this study suggest that the AI-based PBL model was built on a strong theoretical foundation and is well-aligned for implementation in the context of Machining Process Technology instruction. In terms of practicality, the overall score of 80,99 %—comprising 84,09 % from lecturers and 77,90 % from students—reflects a high degree of usability and favorable user reception. This supports Julie's,[36] assertion that practicality encompasses not only the ease of use but also the feasibility of applying the model in real classroom settings. The small-scale practicality test revealed no major obstacles, indicating a strong potential for successful integration of AI-driven instructional innovations.

The final phase of this study involves evaluating effectiveness, which is determined through the post-test scores of students from both the experimental and control groups. The post-test was administered after each group underwent different instructional treatments. This assessment aims to determine how well the developed learning program enhances student academic performance. Additionally, it serves to measure students' final competencies following the applied interventions. The analysis of the post-test results of both groups was conducted using SPSS, and the significance value (Sig. 2-tailed) was obtained as 0,000 <0,05. This value indicates that there is a significant difference in learning outcomes between the experimental group and the control group at the end of the lecture.[37] Based on these findings, it can be concluded that the development of the AI-based PBL model is able to encourage the improvement of students' critical thinking skills, which in turn contributes positively to the improvement of their learning outcomes.

CONCLUSIONS

The findings of this study demonstrate that the implementation of an AI-based Problem-Based Learning (PBL) model in the *Machining Process Technology* course has effectively enhanced students' critical thinking skills. This improvement was validated through the use of evaluation instruments designed with Higher-Order Thinking Skills (HOTS) questions at the C4 cognitive level and above. The primary objective of this study was to develop, validate, and evaluate the effectiveness of an AI-integrated PBL model that is not only theoretically sound but also practically applicable and impactful in improving students' cognitive performance. The study results confirmed that the developed model met the standards of validity, practicality, and effectiveness, making it suitable for integration into instructional practices. Furthermore, the model proved to be a valuable pedagogical tool, particularly for theoretical classroom learning, as it enabled students to critically analyze and address various complex, discipline-related problems. In line with the research objectives, it is recommended that the AI-based PBL model be more widely implemented by lecturers and other stakeholders in the delivery of the *Machining Process Technology* course or similar subjects that aim to foster students' higher-order thinking abilities.

REFERENCES

1. Jenita J, Ratna Nurdiana, I Made Gede Ariestova Kurniawan, Darnilawati, Diana Triwardhani. Optimizing Human Resources Management For Higher Education in the Era of Implementing an Independent Curriculum in Indonesia. Jurnal Iqra' : Kajian Ilmu Pendidikan. 8 déc 2022;7(2):246 59, https://doi.org/10.25217/ji.v7i2.1803

2. Lachheb A, Leung J, Abramenka-Lachheb V, Sankaranarayanan R. AI in higher education: A bibliometric analysis, synthesis, and a critique of research. Internet and Higher Education. 1 oct 2025;67, https://doi.org/10.1016/j.iheduc.2025.101021

3. Sweeney A, Burke J, Meehan T. The impact of mindful pedagogy on creativity in higher education students, a systematic review. International Journal of Educational Research Open. 1 déc 2025;9, https://doi.org/10.1016/j.ijedro.2025.100504

4. Abbasiantaeb Z, Verberne S, Wang J. Tracing science-technology-linkages: A machine learning pipeline for extracting and matching patent in-text references to scientific publications. Inf Process Manag. 1 nov 2025;62(6), https://doi.org/10.1016/j.ijedro.2025.100504

5. Rubeba AM. Lecturers' teaching competencies towards improving teaching and learning process in universities in Tanzania: Students' perspectives. Vol. 11, Heliyon. Elsevier Ltd; 2025, https://doi.org/10.1016/j.heliyon.2025.e41683

6. Putri KYS, Abdullah Z Bin, Nugrahaeni E, Darmawan R, Latifa. Learning management strategy of communication studies through blended learning in higher education. International Journal of Interactive Mobile Technologies. 2020;14(16):117 32, https://doi.org/10.3991/ijim.v14i16.15725

7. Indartono S, Jaidi N, Darmawati A, Endarwati L, Balakrishnan B, Negeri Yogyakarta U. The Antecedents and Outcomes of Higher Education Student Ethics. International Journal of Innovation, Creativity and Change [Internet]. 2020;11(9):486 507. Disponible à: www.ijicc.net.

8. Nursalam. Glocal Vision to Deconstruct Internationalization in Indonesian Higher Education. Journal of Social Studies Education Research. 2020;11(1):137 52.

9. Choudhury I. Session III B 5 Predicting Student Performance Using Multiple Regression.

10. Terblanche A, van Rooyen AA, Enwereji PC. When teachers become learners: Challenges with the integration of critical thinking into accounting curricula. Think Skills Creat. 1 déc 2025;58.

11. Hadiyanto, Noferdiman, Syamsurizal, Muhaimin, Krisantia I. Students' soft skills, hard skills, and competitiveness (SHC): A suggested model for Indonesian higher education curriculum. International Journal of Learning, Teaching and Educational Research. 1 févr 2021;20(2):218 34, https://doi.org/10.26803/ijlter.20.2.12

12. Cross S, Mangelsdorf S, Valentine L, O'Sullivan S, McEnery C, Scott I, et al. Insights from fifteen years of real-world development, testing and implementation of youth digital mental health interventions. Vol. 41, Internet Interventions. Elsevier B.V.; 2025, https://doi.org/10.1016/j.invent.2025.100849

13. Leibovitch YM, Beencke A, Ellerton PJ, McBrien C, Robinson-Taylor CL, Brown DJ. Teachers' (evolving) beliefs about critical thinking education during professional learning: A multi- case study. Think Skills Creat. 1 juin 2025;56, https://doi.org/10.1016/j.tsc.2024.101725

14. Kaya GN, Beyhan F, İlerisoy ZY, Cudzik J. Evaluation of machine learning applications in building life cycle processes for energy efficiency: A systematic review. Vol. 13, Energy Reports. Elsevier Ltd; 2025. p. 4900 16, https://doi.org/10.1016/j.egyr.2025.04.034

15. Phonna DD, Safitri R, Syukri M. Guided inquiry-based on practicum to improve critical thinking skills on the subject of Newton's law. Dans: Journal of Physics: Conference Series. Institute of Physics Publishing; 2020, https://doi.org/10.1088/1742-6596/1460/1/012129

16. Warsah I, Morganna R, Uyun M, Hamengkubuwono H, Afandi M. The Impact of Collaborative Learning on Learners' Critical Thinking Skills. International Journal of Instruction. 2021;14(2):443 60, https://doi.org/10.29333/iji.2021.14225a

17. Yennita Y, Zukmadini AY. Problem-based learning (PBL) and blended learning in improving critical thinking skills and student learning activities in biochemistry courses. Dans: Journal of Physics: Conference Series. IOP Publishing Ltd; 2021, https://doi.org/10.1088/1742-6596/1731/1/012007

18. Pimdee P, Sukkamart A, Nantha C, Kantathanawat T, Leekitchwatana P. Enhancing Thai student-teacher problem-solving skills and academic achievement through a blended problem-based learning approach in online flipped classrooms. Heliyon. 15 avr 2024;10(7), https://doi.org/10.1016/j.heliyon.2024.e29172

19. Liu Y, Pásztor A. Effects of problem-based learning instructional intervention on critical thinking in higher education: A meta-analysis. Think Skills Creat. 1 sept 2022;45, https://doi.org/10.1016/j.tsc.2022.101069

20. Hidajat FA. A comparison between problem-based conventional learning and creative problem-based learning on self-regulation skills: Experimental study. Heliyon. 1 sept 2023;9(9), https://doi.org/10.1016/j.heliyon.2023.e19512

21. Suhirman S, Prayogi S, Asy'ari M. Problem-Based Learning with Character-Emphasis and Naturalist Intelligence: Examining Students Critical Thinking and Curiosity. International Journal of Instruction. 2021;14(2):217 32, https://doi.org/10.29333/iji.2021.14213a

22. Amini R, Setiawan B, Fitria Y, Ningsih Y. The difference of students learning outcomes using the project-based learning and problem-based learning model in terms of self-efficacy. Dans: Journal of Physics: Conference Series. Institute of Physics Publishing; 2019, https://doi.org/10.1088/1742-6596/1387/1/012082

23. Joshi A, Desai P, Tewari P. Learning Analytics framework for measuring students' performance and teachers' involvement through problem based learning in engineering education. Dans: Procedia Computer Science. Elsevier B.V.; 2020. p. 954 9, https://doi.org/10.1016/j.procs.2020.05.138

24. Murphy C, Connell S, Gantley M, Barrett T. Students' perspectives on the congruence and effectiveness of a problem-based learning approach to teach recovery-oriented practice: A mixed method study. Nurse Educ Pract. 1 mars 2025;84, https://doi.org/10.1016/j.nepr.2025.104298

25. Khan AA, Chaudhari O, Chandra R. A review of ensemble learning and data augmentation models for class imbalanced problems: Combination, implementation and evaluation. Expert Syst Appl. juin 2024;244:122778, https://doi.org/10.1016/j.eswa.2023.122778

26. Adamura F. Problem-based learning in real number topic for practising critical and creative thinking. Dans: Journal of Physics: Conference Series. IOP Publishing Ltd; 2021, https://doi.org/10.1088/1742-6596/1742/1/012038

27. Syahri B, Relationship Level Of Creativity With The Result Of Subjects Engineering Drawing. Jurnal Vomek. 2020;2(2):2656 1697, https://doi.org/10.24036/vomek.v4i4.441

28. Yusuf R, Putra I. Critical Thinking and Learning Outcomes through Problem Based Learning Model Based on LBK Application [Internet]. Vol. 12, International Journal of Innovation, Creativity and Change. www.ijicc.net. Disponible à: www.ijicc.net

29. Khoiriyah U, Roberts C, Jorm C, Van Der Vleuten CPM. Enhancing students' learning in problem based learning: Validation of a self-assessment scale for active learning and critical thinking. BMC Med Educ. 26 août 2015;15(1), https://doi.org/10.1186/s12909-015-0422-2

30. Oktradiksa A, Bhakti CP, Kurniawan SJ, Rahman FA, Ani. Utilization artificial intelligence to improve creativity skills in society 5.0. Dans: Journal of Physics: Conference Series. IOP Publishing Ltd; 2021, https://doi.org/10.1088/1742-6596/1760/1/012032

31. Media A, Engreini S, Amini R, Alfana YD. Effectiveness of Using Artificial Intelligence Chatbox Integrated Case Method on Science Learning Outcomes of Basic Education Students. Jurnal Penelitian Pendidikan IPA [Internet]. 2025;11(1):1206 14. Disponible à: http://jppipa.unram.ac.id/index.php/jppipa/index, https://doi.org/10.29303/jppipa.v11i1.9815

32. Marbun TO. The Implementation of Artificial Intelligence, Chatgpt, And Critical Thinking Method for Academic Endeavors at Theological Higher Education. Journal Didaskalia. 31 oct 2023;6(2):84 100, https://doi.org/10.33856/didaskalia.v6i2.309

33. Budiwan J, Hidayatullah F, Yusuf M, Asrowi. Validity test of the family supported collaborative learning (FSCL) model to instill character values to junior high school students. Universal Journal of Educational Research. 2020;8(3D):1 6, https://doi.org/10.13189/ujer.2020.081701

34. Asrizal, Desnita, Darvina Y. Analysis of validity and practicality test of physics enrichment e-book based on CTL and enviromental factor. Dans: Journal of Physics: Conference Series. IOP Publishing Ltd; 2021, https://doi.org/10.1088/1742-6596/1876/1/012034

35. Bom JAM, Voormolen DC, Brouwer WBF, de Bekker-Grob EW, van Exel J. Construct Validity, Reliability, and Responsiveness of the 10-Item Well-Being Instrument for Use in Economic Evaluation Studies. Value in Health. 1 juill 2024;27(7):871 8, https://doi.org/10.1016/j.jval.2024.02.014

36. Manz JA, Todd MJ, Iverson L, Ball SJ, Manning L, Topp R. Validity and reliability testing of the Creighton Competency Evaluation Instrument 2.0© (CCEI 2.0). Clin Simul Nurs. 1 juin 2025;103, https://doi.org/10.1016/j.ecns.2025.101736

37. Nandiyanto ABD, Hofifah SN. How to conduct paired-t-test SPSS: comprehension in adsorption with bibliometric. International Journal of Evaluation and Research in Education . 1 févr 2024;13(1):151 8, https://doi.org/10.11591/ijere.v13i1.27541

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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