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Design of a Problem-Based Learning-Based Physics Laboratory on Energy: Analysis of High School Students' Self-Efficacy and Science Process Skills with AI Integration

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Abstract

This study aims to analyze students' self-efficacy and science process skills as a basis for developing a Problem-Based Learning (PBL)-based physics laboratory design integrated with Artificial Intelligence (AI). A mixed-methods approach was used with a sample of 46 high school students. Data were collected via a questionnaire and analyzed using quantitative descriptive methods based on percentage categories. The results of the study indicate that students' self-efficacy was in the range of ±70% (high category: 51%–75%), science process skills at ±69% (high category: 51%–75%), and perceptions regarding the use of AI at ±68% (high category: 51%–75%). Some indicators even reached the very high category (76%–100%), such as the use of AI in understanding physics concepts (80.43%). However, some indicators were still in the low category (26%–50%), such as independence in designing experiments (46.74%) and doubts and concerns regarding AI use (45.65%–49.46%). Additionally, there was a tendency for students to accept information from AI without critical verification. These findings highlight the need to develop PBL-AI-based physics laboratory designs that not only integrate technology but also emphasize strengthening students' independence, critical thinking skills, and the validation of scientific information.

Penelitian ini bertujuan untuk menganalisis kebutuhan self-efficacy dan keterampilan proses sains siswa sebagai dasar pengembangan desain praktikum fisika berbasis *Problem-Based Learning* (PBL) yang terintegrasi dengan *Artificial Intelligence* (AI). Metode yang digunakan adalah *mixed methods* dengan subjek sebanyak 46 siswa SMA. Data dikumpulkan melalui angket dan dianalisis secara deskriptif kuantitatif berdasarkan kategori penilaian persentase. Hasil penelitian menunjukkan bahwa self-efficacy siswa berada pada kisaran ±70% (kategori tinggi: 51%–75%), keterampilan proses sains sebesar ±69% (kategori tinggi: 51%–75%), dan persepsi terhadap penggunaan AI sebesar ±68% (kategori tinggi: 51%–75%). Beberapa indikator bahkan mencapai kategori sangat tinggi (76%–100%), seperti pemanfaatan AI dalam memahami konsep fisika (80,43%). Namun demikian, masih ditemukan indikator pada kategori rendah (26%–50%), seperti kemandirian dalam merancang percobaan (46,74%) serta keraguan dan kekhawatiran dalam penggunaan AI (45,65%–49,46%). Selain itu, terdapat kecenderungan siswa menerima informasi dari AI tanpa verifikasi kritis. Temuan ini menunjukkan perlunya pengembangan desain praktikum fisika berbasis PBL-AI yang tidak hanya mengintegrasikan teknologi, tetapi juga menekankan penguatan kemandirian, kemampuan berpikir kritis, dan validasi informasi ilmiah siswa.

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1. Introduction

Physics education at the high school level plays a strategic role in fostering conceptual understanding, scientific thinking skills, and students' readiness to face the challenges of 21st-century science and technology [1]. Physics serves not only as a theoretical discipline but also as a means to develop essential science process skills, problem-solving abilities, and scientific literacy for future generations. Physics education is expected to move beyond a transmissive approach and instead be oriented toward knowledge construction through active learning experiences [2]. Therefore, laboratory activities are a fundamental component of physics education because they provide students with opportunities to engage in direct observation, experimentation, and scientific reflection [3]. However, various studies indicate that the implementation of physics laboratory activities in schools still faces challenges regarding instructional design, student engagement, and the effectiveness of scientific competency development. In addition, physics learning is often perceived as difficult due to its abstract concepts and the difficulty of relating them to everyday life, thereby requiring students to have additional learning resources that can be understood independently to support the learning process.[4]

Physics education also supports the implementation of Education for Sustainable Development (ESD) by developing students' critical thinking, problem-solving skills, and scientific literacy needed to address sustainability challenges in the 21st century. Through meaningful laboratory activities, students can better understand scientific concepts and their application to sustainable development goals (SDGs), particularly in quality education and innovation.

A number of previous studies have highlighted the importance of innovative laboratory design in improving the quality of science learning. Research by [5] shows that systematically designed laboratory activities can significantly improve students' conceptual understanding and scientific process skills. Another study by [6] found that the implementation of Problem-Based Learning in science education can improve students' problem-solving skills as well as their active engagement in the learning process. Additionally, [7] emphasize that empirical experiences through laboratory experiments play a crucial role in building students' conceptual understanding through the process of knowledge construction. [8] also reported that a problem-based learning approach can improve students' critical and collaborative thinking skills in science learning. Meanwhile, [9] emphasized that strengthening science process skills through laboratory activities is a key factor in developing students' science literacy at the secondary school level. Nevertheless, most of these studies still focus on the effectiveness of learning models or laboratory activities in general, without thoroughly examining the relationship between students' psychological factors—such as self-efficacy and science process skills—and the potential for integrating digital technologies, such as artificial intelligence, into the design of physics laboratory activities. Thus, there is a research gap indicating the need for a comprehensive study on how students' self-efficacy and science process skills can serve as a foundation for designing Problem-Based Learning-based physics laboratory activities integrated with AI technology.

Physics laboratory sessions serve as a vital platform for developing science process skills, which include the ability to observe, classify, measure, formulate hypotheses, design experiments, interpret data, and draw conclusions [10]. Science process skills are viewed as the foundation for inquiry-based science learning and higher-order scientific thinking. Scientific knowledge is constructed through the interaction between students' empirical experiences and cognitive structures, making laboratory work an authentic means of building conceptual understanding [11]. Furthermore, inquiry-based learning and Problem-Based Learning (PBL) approaches are widely recommended in science education because they encourage students to actively construct knowledge through contextual problem-solving [12]. Therefore, designing PBL-based physics laboratory experiments is a promising pedagogical strategy for improving the quality of physics learning in secondary schools.

Problem-Based Learning is a student-centered learning approach in which learning begins with authentic problems that drive the processes of investigation, collaboration, and reflection. Theoretically, PBL is rooted in social constructivism, which emphasizes the role of social interaction and knowledge construction [13]. In physics education, PBL can be integrated into laboratory activities to encourage students to simultaneously develop critical thinking, problem-solving, and scientific skills. Several studies indicate that PBL in science education can enhance students' conceptual understanding, learning motivation, and scientific process skills. However, the effectiveness of PBL in physics laboratory sessions is highly dependent on instructional design, student readiness, and psychological factors such as self-efficacy.

Self-efficacy is a key concept in Bandura's social cognitive theory, referring to an individual's belief in their ability to perform specific tasks and achieve desired goals. Students' self-efficacy plays a crucial role in determining their level of engagement, persistence, and academic performance.

Students with high self-efficacy tend to be more confident in conducting experiments, asking scientific questions, and solving complex problems. Conversely, students with low self-efficacy tend to avoid challenging tasks and show low levels of participation in laboratory activities [14]. Therefore, understanding students' levels of self-efficacy is essential for designing effective and inclusive laboratory learning.

Students' science process skills are also influenced by instructional design and the learning environment. The theory of experiential learning emphasizes that direct experience through experimentation and reflection is the primary mechanism in the formation of scientific knowledge. Physics lab sessions serve not only as activities for verifying concepts but also as inquiry processes that encourage students to independently build conceptual understanding. However, various studies indicate that lab sessions in schools are often procedural in nature and do not provide space for students to engage in exploration and problem-solving. This results in students' science process skills not developing optimally, and physics learning tends to be mechanistic.

Advances in digital technology and artificial intelligence (AI) are opening up new opportunities in the design of physics instruction, particularly in laboratory activities. AI can be used to provide virtual experiment simulations, intelligent tutoring systems, automated data analysis, and adaptive feedback for students. The integration of AI into science education is viewed as a pedagogical innovation that can enhance the personalization of learning and the effectiveness of problem-based learning. However, the implementation of AI in high school physics lab activities, particularly in developing countries, remains very limited and lacks pedagogical structure. Therefore, a comprehensive needs analysis is required to ensure that the integration of AI in physics lab activities aligns with students' characteristics in the learning process [15].

Although numerous studies have been conducted on PBL, self-efficacy, and science process skills, most of these studies still treat these three variables separately. Research that integrates these three aspects into the design of physics laboratory sessions remains relatively limited. Furthermore, studies on the integration of AI into physics laboratory sessions generally focus on the technical aspects of software development rather than on the analysis of students' pedagogical needs. This indicates a research gap in understanding how students' self-efficacy and science process skills can serve as a foundation for designing PBL-based physics laboratory sessions integrated with AI. Thus, this study aims to address this gap by conducting an analysis of student needs as the foundation for developing innovative instructional designs.

The challenges of teaching physics are becoming increasingly complex due to differences in school facilities, teacher competencies, and students' readiness to use digital technology. The implementation of physics laboratory experiments is often hindered by limited laboratory equipment and teaching time. Furthermore, students' levels of self-efficacy and science process skills vary significantly across different regions. Therefore, analyzing student needs is a crucial first step before developing a PBL-based physics lab design that integrates AI. This needs analysis is expected to provide an empirical picture of students' actual conditions as a basis for pedagogical decision-making.

Based on this background, this study aims to analyze students' self-efficacy levels and science process skills as a foundation for designing physics laboratory sessions based on Problem-Based Learning with the integration of Artificial Intelligence. Specifically, this study aims to identify students' self-efficacy profiles, levels of science process skills, and the pedagogical implications of these findings for the design of innovative physics laboratory sessions. The results of this study are expected to provide theoretical contributions to the development of PBL- and AI-based physics learning, as well as practical contributions for teachers and curriculum developers in designing effective and adaptive physics learning. Furthermore, this study is expected to enrich the international literature on the integration of psychological, pedagogical, and technological factors in science education.

2. Method

This study employed a mixed-methods approach by combining quantitative and qualitative data within a single study to obtain a comprehensive understanding of students' needs in designing AI-supported Problem-Based Learning (PBL) physics laboratory activities [16]. The quantitative data were collected through questionnaires measuring students' self-efficacy, science process skills, and perceptions of the use of artificial intelligence (AI) in laboratory learning. Meanwhile, the qualitative aspect was conducted through comparative analysis and interpretation of the findings with previous relevant studies to strengthen the discussion and pedagogical implications of the study.

The research was conducted at a senior high school in Indonesia involving forty-six (46) science-track students as research participants. The participants were selected using purposive sampling because they had experience in physics laboratory learning activities relevant to the objectives of this study.

All respondents completed the research instruments independently through self-administered questionnaires without the direct presence of the researcher. This technique was chosen because it allows respondents to answer honestly and reflectively according to their personal experiences during laboratory learning activities.

The research instruments consisted of three types of questionnaires: (1) the PBL-AI laboratory self-efficacy questionnaire containing 24 statements, (2) the PBL-AI science process skills questionnaire containing 32 statements, and (3) the questionnaire on students' perceptions of AI use in laboratory sessions containing 16 statements. All questionnaires used a four-point Likert scale with a score range of 1–4 according to the characteristics of each indicator.

The data analysis technique employed an interactive cycle model comprising the stages of data collection, data reduction, data presentation, and drawing conclusions [17]. Quantitative data obtained from the questionnaire were analyzed using descriptive statistics, including total scores, mean values, and percentages, to describe trends in self-efficacy, science process skills, and students' perceptions of AI in the laboratory. The percentage was calculated using the formula:

$$P = \frac{Actual\ Score}{Maximum\ Score} \times 100\%$$

The determination of assessment categories was based on specific percentage ranges as presented in Table 1.

Table 1. Assessment Categories Based on Percentage Ranges

Category	Score Range (in %)	Interpretation of Self-Efficacy/KPS/Perception
Very High	76% - 100%	Students are very confident/skilled/positive
High	51% - 75%	Students are confident/skilled/positive
Low	26% - 50%	Students are less confident/less skilled/less positive
Very Low	0% - 25%	Students are not confident/not skilled/negative

Meanwhile, qualitative data were analyzed using thematic analysis by grouping the meanings of the instrument indicators into the main research themes, namely (1) self-efficacy in PBL-AI-based laboratory work, which includes confidence in designing experiments, utilizing AI, resilience in the face of errors, and the transfer of learning strategies; (2) PBL-AI science process skills, which include observation, classification, data interpretation, prediction, hypothesis formulation, experiment design, use of tools, and communication of results; and (3) perceptions regarding the use of AI in laboratory sessions, which include perceptions of benefits, ease of use, trust, and potential barriers to AI use in laboratory learning. The integration of quantitative and qualitative analysis results was conducted during the final interpretation stage to obtain a more comprehensive understanding in accordance with the principles of mixed methods. The systematic research process flow, from data collection to drawing conclusions, is presented in Figure 1

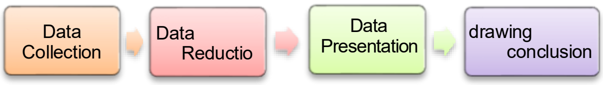

Figure 1. Research Methodology Flowchart

3. Results

Based on the research method described above, data were collected using a Likert-scale questionnaire administered to students from two high schools in Palangka Raya City that implement the Merdeka Curriculum in science education. The questionnaire instrument consisted of three aspects: practical self-efficacy, science process skills (SPS), and students' perceptions of AI use in practical work. Quantitative data were analyzed using descriptive statistics by calculating scores and percentages for each indicator. The results and discussion of the research findings are presented in an integrated manner in the following section.

Table 2. Results of the PBL-AI Lab Self-Efficacy Questionnaire

No	Question Indicator	Dimension	Total Score	Percentage (%)	Category
1	I am confident that I can design my own experimental steps even if the worksheet does not provide detailed procedures.	Magnitude	109	59.24%	High
2	I am confident that I can determine the appropriate tools and materials to test hypotheses in physics lab experiments.	Magnitude	119	64.67%	High
3	I am confident that ChatGPT/AI can help me understand the theory behind physics	Magnitude	135	73.37%	High

	experiments.				
4	I am confident I can formulate the right questions for AI to get useful explanations for the lab	Magnitude	136	73.91%	High
5	If my experimental data does not match the theory, I am confident I can identify the cause of the error.	Strength	129	70.11%	High
6	I am confident that failures in the lab actually help me better understand physics concepts.	Strength	146	79.35%	Very High
7	If the AI provides an answer that does not align with what I have learned, I will double-check its accuracy using other sources.	Strength	158	85.87%	Very High
8	I am confident that I can correct AI errors by asking more specific questions.	Strength	136	73.91%	High
9	I am confident that the methods for designing experiments in the Work and Energy unit can also be applied to the Impulse and Momentum unit.	Generality	119	64.67%	High
10	I believe the habit of asking "why is that?" during lab sessions will be useful in all physics topics.	Generality	160	86.96%	Very High
11	I am confident that the methods for asking AI questions that I learned in physics can be applied to other subjects (biology, chemistry, etc.).	Generality	135	73.37%	High
12	I believe that the ability to verify AI information will be useful throughout my life.	Generality	119	64.67%	High
13	I can only perform lab experiments if the procedures have been fully written out by the teacher.	Magnitde	86	46.74%	Low
14	I'm unsure where to start when given the freedom to design my own experiments.	Magnitde	96	52.35%	High
15	I doubt that AI can provide accurate information about physics.	Magnitde	100	54.35%	High
16	I trust textbooks more than explanations from AI.	Magnitde	95	51.63%	High
17	When my calculations differ from the theory, I immediately assume I'm the one who's wrong.	Strength	101	54.89%	High
18	I'm reluctant to repeat a failed lab even if there's still time.	Strength	148	80.43%	Very High
19	I stop using AI immediately if its first answer is wrong.	Strength	130	70.65%	High
20	I simply trust the AI's answers without verifying their accuracy.	Strength	150	81.52%	Very High
21	Every new physics topic feels like a foreign lesson with no connection to previous lab experiments.	Generality	133	72.28%	High
22	I can only perform lab experiments that are exactly the same as the teacher's example.	Generality	105	57.07%	High
23	AI is only useful for physics, not for other subjects.	Generality	163	88.59%	Very High
24	I doubt AI can help in non-science subjects.	Generality	136	73.91%	High

Table 3. Results of the PBL-AI Science Process Skills (SPS) Questionnaire

No	Question Indicator	SPS Aspect	Total Score	Percentage (%)	Category
1	I am able to carefully observe physical phenomena in laboratory experiments (e.g., temperature changes, object motion, light bulb illumination).	Observation	126	68.48%	High
2	I use AI to verify whether my observations are scientifically plausible.	Observation	123	66.85%	High
3	I am able to classify data based on independent, dependent, and control variables.	Classification	112	60.87%	High
4	I use AI to help identify patterns in the data I have obtained.	Classification	126	68.48%	High
5	I am able to interpret data presented in tables or graphs to draw conclusions.	Interpretation	120	65.22%	High
6	I compare my interpretation with the AI's interpretation to see if there are other perspectives.	Interpretation	129	70.11%	High
7	Before the lab, I am able to predict what will happen based on the theory I have learned.	Prediction	108	58.70%	High
8	I compare my predictions with AI predictions to test the accuracy of my analysis.	Prediction	134	72.83%	High
9	I was able to formulate a tentative hypothesis indicating the relationship between variables.	Hypothesis	121	65.76%	High
10	I used AI to search for supporting theories before formulating a hypothesis.	Hypothesis	139	75.54%	Very High
11	I am able to select the appropriate tools and materials to test a hypothesis.	Experiment Planning	121	65.76%	High

12	I use AI to explore more efficient experimental design alternatives.	Experiment Planning	132	71.74%	High
13	I am able to operate measuring instruments (stopwatch, multimeter, thermometer, etc.) correctly.	Using Tools/Materials	123	66.85%	Hih
14	I use AI as a quick guide to remember how to use rarely used tools.	Using Tools/Materials	133	72.28%	High
15	I am able to present lab results in a systematic and easy-to-understand report.	Communication	122	66.30%	High
16	I use AI to polish grammar or create more engaging data visualizations.	Communication	135	73.37%	High
17	I often overlook important details when conducting lab observations.	Observation	118	64.13%	High
18	I never compare my observation results with information from AI.	Observation	145	78.80%	Very High
19	I have difficulty distinguishing between independent and dependent variables in an experiment.	Classification	119	64.67%	High
20	I prefer to ask the teacher directly rather than trying to analyze data patterns on my own or with AI.	Classification	110	59.78%	High
21	I am confused when reading the graphs of lab results.	Interpretation	126	6.48%	High
22	I simply accept the AI's interpretation without questioning its consistency with my data.	Interpretation	150	81.52%	Very High
23	I can't imagine the outcome of an experiment before conducting it.	Prediction	135	73.37%	High
24	I immediately trust AI predictions without considering other possibilities.	Prediction	152	82.61%	Very High
25	I have trouble formulating a hypothesis because I don't know where to start.	Hypothesis	118	64.13%	High
26	I ask the AI to generate a hypothesis and use it as is.	Hypothesis	144	78.26%	Very High
27	I can only conduct lab experiments using procedures provided by the teacher.	Experiment Planning	103	55.98%	High
28	I never consider redesigning lab procedures even if the existing ones are inefficient.	Experiment Planning	137	74.46%	High
29	I'm afraid of damaging the equipment, so I often ask friends or teachers for help.	Using Equipment/Materials	139	75.54%	Very High
30	I never read the equipment manual; I just try things out.	Using Equipment/Materials	143	77.72%	Very High
31	I have difficulty writing lab reports even though the data is complete.	Communication	163	88.59%	Very High
32	I copy my friends' reports because I lack confidence in my own writing.	Communication	147	79.89%	Very High

Table 4. Questionnaire on Perceptions of AI in Laboratory Session

No	Question Indicator	Dimension	Total Score	Percentage (%)	Category
1	AI (ChatGPT/DeepSeek/simulation) helps me understand difficult physics concepts in laboratory sessions.	Perceived Usefulness	148	80.43%	Very High
2	I helps me design better lab procedures.	Perceived Usefulness	139	75.54%	Very High
3	AI helps me analyze lab data more quickly.	Perceived Usefulness	140	76.09%	Very High
4	AI is easy to use (just type the question in Indonesian).	Perceived Ease of Use	142	77.17%	Very High
5	AI responds quickly, so it doesn't hinder the lab session.	Perceived Ease of Use	140	76.09	Very High
6	I believe the AI's answers are accurate enough to assist with physics lab work.	Trust in AI	113	61.41%	High
7	The AI demonstrates the thought process (doesn't immediately provide the final answer), so I can learn.	Trust in AI	141	76.63%	Very High
8	I am confident I can use AI independently without the teacher's help.	AI Self-Efficacy	116	63.04%	High
9	AI makes me lazy because I just copy the answers.	Perceived Usefulness	107	66.85%	High
10	AI's explanations are too general and not relevant to my lab.	Perceived Usefulness	121	59.24%	High
11	AI is difficult to use because it requires a stable internet connection.	Perceived Ease of Use	124	54.89%	High

12	The English language used in AI is a barrier for me.	Perceived Ease of Use	93	74.46	High
13	I doubt the accuracy of AI's answers because they are often incorrect.	Trust in AI	139	49.46%	Low
14	AI lacks transparency (does not cite information sources).	Trust in AI	125	57.07%	High
15	I'm afraid of misusing AI and getting incorrect information.	AI Self-Efficacy	146	45.65	Low
16	I'm more confident without AI because I'm afraid of becoming dependent on it.	AI Self-Efficacy	126	56.52	High

4. Discussion

4.1. Analysis of Students' Self-Efficacy in PBL-AI-Based Laboratory Sessions

Based on the survey results in Table 1, most of the students' self-efficacy indicators fall into the high to very high categories. This indicates that students have a fairly high level of confidence in conducting laboratory experiments and utilizing AI to help them understand concepts and solve problems during experiments. However, there are still several indicators in the low category, suggesting that some students still face difficulties when designing experiments independently without detailed guidance from the teacher.

The self-efficacy aspect of the PBL-AI laboratory sessions shows that most indicators fall into the high to very high categories. These findings indicate that students generally possess a fairly strong sense of self-confidence in conducting physics laboratory sessions, whether in understanding concepts, dealing with errors, or utilizing AI as a learning aid. This is evident in the high scores for the indicator of confidence that laboratory failures can deepen understanding of physics concepts (79.35%), the habit of asking "why is that?"—which was deemed useful across all physics topics (86.96%) and the ability to cross-check AI answers against other sources when they seem inappropriate (85.87%). These findings indicate that problem-based laboratory activities can encourage students' active engagement and boost their confidence in the learning process. This aligns with research [14], which found that the implementation of Problem-Based Learning in science education can enhance problem-solving skills and students' active engagement in the learning process. In addition, a study [8] also reported that a problem-based learning approach can improve students' critical and collaborative thinking skills. However, a weakness was still found in the indicator that students could only conduct laboratory experiments if the procedures were fully written out by the teacher (46.74%). This condition indicates that although students are generally quite confident, some of them are still not fully independent in designing experiments. This suggests that laboratory activities in schools still tend to be procedural in nature, so students are not yet accustomed to developing experimental initiatives independently.

4.2. Analysis of Science Process Skills in the Context of PBL-AI

The survey results in Table 2 show that students' science process skills generally fall into the high to very high categories. This indicates that students are quite capable of performing scientific activities such as observing, organizing data, formulating hypotheses, and interpreting laboratory results. In addition, the use of AI also helps students in finding supporting theories and analyzing laboratory data.

The science process skills (SPS) aspects of PBL-AI tend to fall into the high to very high categories. This indicates that students are quite capable of performing scientific activities such as observing, classifying, interpreting data, predicting, formulating hypotheses, planning experiments, using tools, and communicating results. These achievements are evident in the indicators of using AI to search for supporting theories before formulating hypotheses (75.54%), the ability to compare one's own predictions with AI predictions (72.83%), and the use of AI to improve the quality of communication regarding lab results (73.37%). These findings suggest that lab activities provide learning experiences that support the development of students' scientific skills. This aligns with research [5] showing that systematically designed laboratory activities can significantly enhance both students' conceptual understanding and their scientific process skills. Additionally, research (Kamilah & Lause, 2025) also confirms that strengthening scientific process skills through laboratory activities is a key factor in developing students' science literacy at the secondary school level. These findings are also supported by research [7] which states that empirical experiences through laboratory experiments play a crucial role in building students' conceptual understanding through the process of knowledge construction. However, several indicators also point to a tendency toward reliance on AI, such as students accepting AI interpretations without questioning their alignment with the data (81.52%), immediately trusting AI predictions without considering other possibilities (82.61%), and simply adopting hypotheses generated by AI (78.26%). This situation indicates that although students' science process skills are developing well, their critical attitudes toward the use of AI still need to be strengthened.

4.3. Analysis of Students' Perceptions of AI Adoption

Based on Table 3, students' perceptions of the use of AI in physics lab sessions generally fall into the high to very high categories. AI is considered helpful in understanding concepts, designing procedures, and analyzing lab data, and is also considered easy to use. However, some indicators show low ratings, particularly regarding uncertainty about the use of AI and concerns about using it appropriately.

Students' perceptions of the use of AI in laboratory sessions generally fall into the high to very high categories. This indicates that students view AI as a useful and relatively easy-to-use tool in physics laboratory learning. These findings are evident in the indicators that AI helps students understand difficult physics concepts (80.43%), helps design better lab procedures (75.54%), helps analyze lab data more quickly (76.09%), and is easy to use simply by typing questions in Indonesian (77.17%). These findings suggest that the integration of technology in laboratory learning can support the effectiveness of students' learning processes. This aligns with the perspective of [2], who assert that the integration of technology in science education can enhance learning effectiveness and facilitate students' access to scientific information. Additionally, the use of digital technology in learning can support the design of more adaptive laboratory experiments that keep pace with technological advancements. However, the research results also indicate several low indicators, particularly regarding doubts about the accuracy of AI answers (49.46%) and fears of misusing AI, leading to incorrect information (45.65%). This suggests that while students hold positive perceptions of AI, concerns persist regarding the accuracy of information and the potential for dependency on this technology.

4.4. Implications for the Design of PBL-AI-Based Physics Laboratory Courses

Overall, the results of the needs analysis indicate that students already possess a solid foundation for participating in a Problem-Based Learning-based physics laboratory design that integrates AI. Students' self-efficacy is relatively strong, their science process skills are at an adequate level, and their perceptions of AI tend to be positive. These findings reinforce previous studies highlighting the importance of innovative laboratory design in enhancing the quality of science learning [5], [6], [9]. However, most previous research has primarily focused on the effectiveness of learning models or laboratory activities in general. Therefore, this study makes an additional contribution by highlighting the relationship between students' self-efficacy, science process skills, and the integration of AI technology as a foundation for designing Problem-Based Learning-based physics laboratory activities that are more adaptable to advancements in educational technology.

The findings of this study also provide practical implications for teachers, schools, and curriculum developers. Physics teachers can use these findings as a basis for designing Problem-Based Learning laboratory activities integrated with AI to improve students' self-efficacy, science process skills, and engagement in laboratory learning. Schools may support the implementation of AI-assisted laboratory learning by providing adequate technological facilities and professional development programs for teachers. Furthermore, curriculum developers can integrate AI literacy, problem-solving skills, and inquiry-based laboratory activities into science curricula to support 21st-century learning and Education for Sustainable Development (ESD).

5. Conclusion

Based on the research findings, it can be concluded that students' self-efficacy averaged approximately ±70% (high category: 51%–75%), their science process skills averaged ±69% (high category: 51%–75%), and their perceptions regarding the use of Artificial Intelligence (AI) are at ±68% (high category: 51%–75%). This indicates that students are well-prepared to implement physics laboratory sessions based on Problem-Based Learning (PBL) integrated with AI.

Prominent indicators in the very high category (76%–100%) include:

(1) the belief that laboratory failures enhance conceptual understanding (79.35%),
(2) the ability to verify AI answers against other sources (85.87%),
(3) the habit of critical thinking through "why" questions (86.96%), and
(4) the perception of AI's usefulness in understanding physics concepts (80.43%).

However, several indicators were found in the low category (26%–50%), namely:

(1) independence in designing experiments without guidance (46.74%),
(2) doubt regarding AI accuracy (49.46%), and
(3) anxiety regarding the use of AI (45.65%). Additionally, there is a tendency for students to accept information from AI without critical verification, indicating a potential reliance on technology.

The main finding of this study is that although students have high self-efficacy and science process skills, they still show low experimental independence and tend to rely on AI during scientific thinking activities. Therefore, PBL-AI-based laboratory learning should not only integrate technology but also strengthen students' critical thinking and independence. These findings support Bandura's Social Cognitive Theory and constructivist learning principles. However, this study was limited by the relatively small number of participants and the focus on needs analysis. Future research should involve larger samples and direct implementation of PBL-AI laboratory learning.

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