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Effect of Learning Intervention on the Improvement of Students' Questioning Skills in Physics Learning

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Abstract: This study aims to reveal the effect of a learning intervention on the questioning ability in physics learning of the students of SMA Negeri 1 Kuta Baro. Employing a quantitative approach with a nonequivalent control group quasi-experimental design, the research involved 84 students, comprising 41 students in the experimental group (Classes X-1 and XI-1) and 43 students in the control group (Classes X-2 and XI-2). The learning intervention in the experimental class integrated the problem-based learning (PBL) model, teacher-student question-and-answer interactions, collaborative group discussions, and inter-group Q&A sessions. The research results showed that the learning intervention significantly and substantially enhanced students' questioning ability, as measured by the dimensions of questioning skills, including clarity, focus, conciseness, depth of information, and cognitive level. There was a 27.56% increase in the quantity of written questions in the experimental class, far exceeding the 7.9% increase in the control class. Although the quantity of oral questions increased in the experimental class, the cognitive level of oral questions in both groups remained low; however, their effectiveness (clarity and focus) was categorized as high. Overall, the learning intervention proved effective in facilitating the development of students' questioning skills, although further strategies were still needed to encourage questions at higher cognitive levels. Further follow-up is required to enhance students' oral questioning ability at the mental level by improving their prior knowledge of the subject matter and critical thinking skills.

Keywords: physics learning intervention, problem-based learning, questioning ability

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INTRODUCTION

Questioning ability stands as a fundamental cognitive skill, indispensable in sparking intellectual curiosity and fostering deep understanding throughout the learning process. This essential skill is defined as a verbal expression serving to elicit informative responses or acquire structured considerations, effectively stimulating students' thinking capabilities (Indriyani & Rohita, 2019; Supena et al., 2021). As a form of active participation, providing students with opportunities to ask questions in class is a standard method teachers use to engage learners in the subject matter (Nadile et al., 2021).

Beyond a mere passive assessment tool, questioning ability is a crucial teaching and learning strategy that actively stimulates imagination, nurtures the seeds of curiosity, and consistently cultivates students' intellectual thirst for new knowledge (Ishtiaq & Gul, 2024). Through a repetitive and active process of inquiry, students hone their critical thinking skills directly, taking a proactive role in seeking relevant information and constructing their own understanding of the world (Salamah et al., 2022). Thus, by initiating questions and diligently seeking answers, students systematically develop relevant and adaptive problem-solving skills, preparing them to face cognitive challenges across various contexts (Prilanita & Sukirno, 2017).

Within the realm of science education, particularly in the field of physics, the ability to question gains increasingly crucial relevance. Physics, often referred to as the foundation of natural sciences, not only equips students with theoretical understanding but also empowers them to interpret and comprehend their surrounding environment through the investigation of phenomena rooted in concrete problems (Nuriya et al., 2022). Physics learning is not merely a passive information transfer process, but rather a dynamic process oriented towards developing a comprehensive understanding of the universe, inherently encouraging students to engage actively in the scientific process itself. In the context of this active engagement, students' capacity to pose questions emerges as one of the most significant indicators of their participation and deep understanding (Nadile et al., 2021; Puente & Kroesen, 2020).

Given the often-abstract nature of physics concepts and the complexity of the underlying cause-and-effect relationships, questioning ability plays a central role in facilitating deep conceptual understanding (Chung et al., 2024). When students ask questions, they are not just seeking answers. However, they are actively processing new information, connecting it with their prior knowledge, and carefully identifying areas of ambiguity or uncertainty in their comprehension. This active cognitive process significantly enhances their cognitive engagement, shifting them from passive recipients to active participants in the construction of knowledge (Nurdiansyah et al., 2019).

Furthermore, social cognitive theory provides a valuable perspective on how social interactions and observations within the learning environment significantly shape students' questioning abilities (Yanuardianto, 2019). Posing questions during the learning process plays a crucial role in helping students connect existing knowledge with new information, thereby fostering a meaningful and comprehensive understanding through cognitive elaboration (Pramudiyanti et al., 2019; Muliati et al., 2023). Students' questioning ability is significantly influenced by various factors, both internal and external (Nadile et al., 2021; Ishtiaq & Gul, 2024; Salamah et al., 2022). Despite the clear emphasis on the urgency of questioning ability in educational literature, various previous studies consistently indicate significant challenges related to students' low questioning ability in diverse learning contexts, particularly in physics education, both orally and in writing (Aryanti et al., 2020; Evendi et al., 2018; Ishtiaq & Gul, 2024; Salamah et al., 2022; Nadile et al., 2021).

Qualitative analysis of student questions in several studies reveals a concerning pattern regarding the low cognitive level of questions. Studies such as Salamah et al. (2022) and Pramudiyanti et al. (2019) consistently report that most questions posed by students tend to be at the Remembering (C1) and Understanding (C2) levels of Bloom's Taxonomy. Few questions reach higher thinking levels, such as applying (C3), analyzing (C4), evaluating (C5), or creating (C6). This suggests that students continue to struggle to formulate questions that require critical thinking, complex reasoning, or the synthesis of information. In addition to cognitive factors, external factors also play a significant role in inhibiting students' questioning ability (Supena et al., 2021; Toheri et al., 2020).

Studies by Pratiwi et al. (2019) and Kunayah & Fauziah (2023) highlight various barriers, including the fear of making mistakes, a lack of self-confidence, limited opportunities provided by teachers to ask questions, and teacher dominance in classroom discussions. When teachers monopolize the conversation and provide insufficient wait time, students have little room to process information and formulate their questions. These persistent problems collectively confirm that weak questioning ability is a recurring issue that requires targeted intervention and well-planned strategies. This gap indicates an urgent need not only to identify the problems but also to develop and evaluate effective and comprehensive interventions that can proactively address various dimensions of the challenges in students' questioning ability.

To address the critical issue of students' low questioning ability, a learning intervention emerges as a potentially effective solution. Learning intervention is defined as a series of systematically designed and implemented actions or strategies by educators with the explicit goal of enhancing students' questioning capacity in a planned and measurable manner (Navarrete-Ulloa, 2024). The types of interventions can vary widely, encompassing substantial modifications in teaching methods used, the utilization of more innovative and interactive teaching materials, the implementation of specific activities that directly stimulate inquiry, or even direct training focused on effective questioning techniques.

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In the context of this study, the implemented intervention is a synergistic combination of four key strategies that are expected to impact students' questioning ability comprehensively—first, the use of the problem-based learning (PBL) model. The PBL model inherently prompts students to formulate questions due to its problem-centered nature (Islamiati et al., 2024; Putri et al., 2025). Second, the provision of structured questioning opportunities with the teacher. Teacher-student question-and-answer interactions form a crucial foundation for effective learning (Caton et al., 2021). Third, collaborative group discussions among students. Interactions within small groups create a psychologically safe space where students feel more comfortable asking, discussing, and clarifying their understanding with each other without feeling intimidated by the larger class. Fourth, inter-group question-and-answer sessions after presentations. After groups present their work, these Q&A sessions provide an opportunity for students from other groups to ask questions. This promotes critical thinking, active listening skills, and the ability to formulate relevant questions based on peer presentations (Indriyani & Rohita, 2019; Aryanti et al., 2020).

This study examined explicitly the holistic impact of a learning intervention that synergistically combined four key strategies: the problem-based learning (PBL) model, provision of structured questioning opportunities with the teacher, collaborative group discussions among students, and inter-student (inter-group) question-and-answer sessions. A comprehensive analysis was conducted on various dimensions of students' questioning ability, which included the following.

First, question quantity: This was measured by the total number of questions posed by students, both orally and in writing, serving as an indicator of their activeness and initiative in questioning (Ishtiaq & Gul, 2024). The quantity of oral questions was measured through direct observation, recording the total number of questions and the frequency of student questioning per meeting. Meanwhile, the quantity of written questions was measured based on the number of questions posed by students in the open-ended question section of the questioning ability test sheet (Ishtiaq & Gul, 2024).

Second, question quality (cognitive level): Student questions were classified according to the six cognitive levels of Revised Bloom's Taxonomy (C1-C6). Indicators for each cognitive level were based on key verbs and the focus of student questions, reflecting the depth of student understanding and cognitive level (Pramudiyanti et al., 2019). Questions with higher cognitive levels indicate students' ability not only to recall information but also to process, connect, and evaluate concepts (Pramudiyanti et al., 2019).

Third, question quality (effectiveness): The quality of oral questions was also assessed based on their effectiveness, measured through four main criteria (Hafizo et al., 2022). These criteria are: conciseness and clarity, where questions were posed directly and were easy to understand without ambiguity; focus, where questions were directed at a specific issue or concept; being probing or divergent, where questions encourage further thought or open up various possible answers; and precise delivery (for oral questions), where questions were articulated with adequate intonation and volume so they were easily heard and understood. This aspect of effectiveness demonstrates students' ability to formulate questions that not only showed curiosity but were also designed to elicit relevant information or clarification (Hafizo et al., 2022). This measurement of effectiveness is crucial because practical questions can facilitate communication and clarification in the classroom, help students integrate old knowledge with new information, deepen understanding, and enhance long-term memory, as well as offer opportunities to clarify doubts and misconceptions, thereby impacting learning outcomes (Pramudiyanti et al., 2019; Muliati et al., 2023).

The distinctions between oral and written questions are the focus of analysis. Oral questions in physics learning are generally more spontaneous and situational, often arising as a direct response to the teacher's explanations or classroom discussions. Their advantage lies in flexibility and the ability to provide instant clarification or follow-up. Direct interaction allows students to adjust their questions based on the responses they receive. Consequently, oral questions might tend to be shorter and focus on understanding basic concepts or addressing immediate confusion (Nadile et al., 2021).

In contrast, written questions require students to take time to reflect on the material and formulate their questions in a more structured and planned manner. The written format provides an opportunity for students to refer to notes or lesson materials, potentially leading to more reflective and in-depth questions. Written questions allow students to convey their understanding more comprehensively and might include deeper analysis or connections between concepts (Ishtiaq & Gul, 2024; Zuraidah et al., 2019). Providing weekly reflection assignments after experiments, for example, can encourage more in-

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depth written questions about concepts and data analysis. Furthermore, teachers can utilize both types of questions as formative assessment tools to gain a deeper understanding of students' thought processes and identify areas where students may be struggling. By balancing opportunities for both oral and written questioning, teachers can accommodate diverse learning styles and encourage students' questioning ability holistically (Ishtiaq & Gul, 2024).

Building upon the identified challenges and existing gaps in the literature regarding students' questioning abilities in physics, this study addresses the persistent issue of low student engagement in higher-order questioning explicitly. Consequently, the research question for this study is: What is the effect of a learning intervention on the questioning ability in physics learning of the students of SMA Negeri 1 Kuta Baro? Aligned with this, this research aims to investigate the impact of a learning intervention on the questioning ability in physics learning of the students of SMA Negeri 1 Kuta Baro.

METHOD

This study employed a quantitative approach with a quasi-experimental, nonequivalent control group design. This design was chosen to statistically analyze the influence of a learning intervention on the improvement of students' questioning skills in two distinct groups (experimental and control), as well as to identify the distribution of questions. The research was conducted at SMA Negeri 1 Kuta Baro, located at Jalan Blang Bintang Lama Km 11.5, Desa Seupeu, Kecamatan Kuta Baro, Aceh Besar Regency. The planning phase commenced on September 24, 2024. Data collection took place from February 18 to February 25, 2025, with the intervention lasting one week.

The population for this study consisted of all 10th- and 11th-grade students of SMA Negeri 1 Kuta Baro during the 2024/2025 academic year. The research sample was established using a purposive sampling technique, by considering class schedules, availability, and relevant homogeneity characteristics. The sample consisted of two experimental classes and two control classes with a total of 84 students. The experimental classes consisted of 41 students, divided between Class X-1 and Class XI-1. The control classes totaled 43 students, comprising Class X-2 and Class XI-2. The selection of these classes was based on the assumption that they possessed relatively similar initial characteristics in terms of prior physics ability, previous academic performance, and the school's willingness to participate in the intervention.

The research procedure was divided into four main stages: preparation, pre-intervention, intervention, and post-intervention. The preparation stage involved obtaining research permits from the school and securing consent from the participants. All participants were informed about the study's objectives and data collection procedures. Participant anonymity and data confidentiality were guaranteed by not including student names in the research report; identification codes were used to refer to participants.

Before the learning intervention began, a pre-test of questioning skills was administered to all students in both the experimental and control classes. This pre-test aimed to measure students' initial questioning abilities (both the quantity and quality of written questions) as a baseline for post-intervention comparison. The pre-test, along with the post-test, utilized structured written tasks (test sheets) to assess the quantity and various quality dimensions of questions. Oral questioning ability was assessed through direct observations using observation sheets. The learning intervention was conducted during physics lessons, adhering to the school's timetable, with a total of two meetings per class (each consisting of two academic hours or 2 x 45 minutes). The learning material covered static fluid concepts, including hydrostatic pressure, Pascal's law, and Archimedes' principle. It is important to acknowledge that the relatively short duration of two meetings for the intervention may present a limitation in observing profound and sustained changes in students' questioning behavior.

In the experimental classes, the intervention implemented a combination of strategies designed to enhance students' questioning skills. This included the problem-based learning (PBL) model, where the researcher acted as a facilitator, guiding students' understanding of the material through authentic problem-solving. Second, teacher-student question-and-answer interactions were emphasized, with the teacher actively providing opportunities for students to ask questions during lessons and offering constructive feedback. Next, collaborative group discussions were formed, with students divided into four small groups to complete Student Worksheets (LKPD), where they were encouraged to interact and ask each other questions. Finally, inter-group question-and-answer sessions were facilitated following the presentation of LKPD results, aiming to foster interaction and improve questioning. Throughout this process, the quantity and quality of students' oral questions were observed and recorded.

In contrast, the control classes learned using a conventional, teacher-centered lecture method, without specific interventions designed to enhance questioning skills. Observation of questioning ability was also conducted in the control classes for comparative purposes. After the intervention concluded, a post-test of questioning skills was administered to all students in both the experimental and control classes to measure their questioning abilities after the treatment.

To provide a more detailed overview of how students' questioning ability was measured in this study, Table 1 presents the specific indicators of questioning ability and their corresponding measurement methods, encompassing both the quantity and quality of oral and written questions, along with their effectiveness criteria. Specifically, the quantity of questions was measured by counting the number of questions posed. At the same time, the quality dimensions, including clarity, focus, conciseness, depth of information, and cognitive level, were assessed using detailed rubrics. For written questions, these indicators were evaluated from student responses to structured tasks (test sheets). For oral questions, observations were conducted using observation sheets, focusing on both the exact quality dimensions and the overall effectiveness of communication.

Table 1. Questioning Ability Indicators and Measurement Methods

Measurement Aspect	Question Type	Indicator	Measurement Method	Reference Source
Quantity	Oral	Total number of questions	Observation	Ishtiaq & Gul (2024)
		Questioning frequency	Observation	Ishtiaq & Gul (2024)
	Written	Total number of questions	Test	Ishtiaq & Gul (2024)
		Questioning frequency	Test	Ishtiaq & Gul (2024)
Quality	Oral	Cognitive level (C1-C6)	Observation	Pramudiyanti et al. (2019)
	Oral	Question effectiveness	Observation	Hafizo et al. (2022)
	Written	Cognitive level (C1-C6)	Test	Pramudiyanti et al. (2019)

Research data were collected using validated and reliable instruments. The primary instrument was a written test designed to measure both the quantity (number of questions formulated) and quality (cognitive level, based on Bloom's Revised Taxonomy, C1-C6) of student questions. Test items required students to formulate questions based on provided stimuli. The validity of this instrument was established through expert validation by three physics education lecturers who assessed its content and construct validity based on predetermined criteria, ensuring the questions accurately measured the intended cognitive levels. Its reliability was assessed using Cronbach's Alpha reliability testing on a pilot study conducted with students from a non-sample class (Class XII-1), yielding a coefficient of 0.85, indicating high internal consistency and reliability.

Another instrument used by the researcher was an oral questioning skills observation sheet, which recorded the quantity (frequency) of oral questions posed by students during lessons. This sheet also included a rubric to assess the quality of oral questions based on Bloom's Revised Taxonomy cognitive levels (C1-C6) and the effectiveness of the questions. Indicators for oral question effectiveness included: conciseness and clarity, focus, a probing or divergent nature, and precise delivery (Hafizo et al., 2022). The validity of this observation sheet and rubric was established through expert judgment by two experienced physics teachers and one educational psychologist, who evaluated its relevance, clarity, and comprehensiveness. Its reliability was ensured through inter-rater reliability analysis, where two independent observers simultaneously observed and scored student questioning during pilot observations, resulting in a high agreement rate (e.g., Cohen's Kappa = 0.88).

The collected data were analyzed quantitatively using both descriptive and inferential statistics. The JASP software was utilized for statistical analysis. For the quantity of questions, data from both oral and written questions in both groups were analyzed using descriptive statistics (means, frequencies, and percentages). To test the significance of the difference in the improvement of questioning ability (quantity) between the experimental and control classes, an independent samples t-test was applied to the gain scores (post-test scores minus pre-test scores). For question quality, student questions from both tests and observations were classified based on Bloom's Revised Taxonomy (C1-C6) and effectiveness criteria (for oral questions only) through content analysis. Frequency distributions and percentages for each cognitive level and effectiveness category were presented.

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RESULT AND DISCUSSION

This section presents the findings from the administered pre-test and post-test of students' questioning abilities, along with data collected through observation. The discussion will detail the analysis of both the quantity and quality of student questions, encompassing their cognitive levels and effectiveness, across the experimental and control groups. This discussion will then interpret these results in relation to the implemented learning intervention and relevant theoretical frameworks, aiming to address the research objectives concerning the influence of the intervention on students' questioning skills in physics learning.

The data on question quantity showed a notable increase in both groups from the pre-test to the post-test, although with significantly different proportions. In the experimental class, the number of written questions increased from 468 to 597, representing a 27.56% increase. This significant rise can be directly attributed to the implementation of the comprehensive learning intervention, which included the problem-based learning (PBL) model, structured teacher-student question-and-answer interactions, collaborative group discussions, and inter-group Q&A sessions. This increase aligns with the view that providing opportunities for students to ask questions is a standard method for teachers to engage them (Nadile et al., 2021), and it is crucial for developing problem-solving skills (Prilanita & Sukirno, 2017; Nurhasanah et al., 2024). Further details on the quantity of written questions can be found in Table 2.

Table 2. Distribution of student questions

	Experimental Class		Control Class	
Cognitive level	Pre-test	Post-test	Pre-test	Post-test
C1	69	51	77	86
C2	146	158	220	226
C3	23	25	55	70
C4	219	353	166	176
C5	11	10	1	2
C6	0	0	0	0
Amount	468	597	519	560
Percentage	27.56%		7.90%	

The data on question quantity showed a notable increase in both groups from the pre-test to the post-test, although with significantly different proportions. In the experimental class, the number of written questions increased from 468 to 597, representing a 27.56% increase. For easier understanding, please refer to Figure 1 below**.**

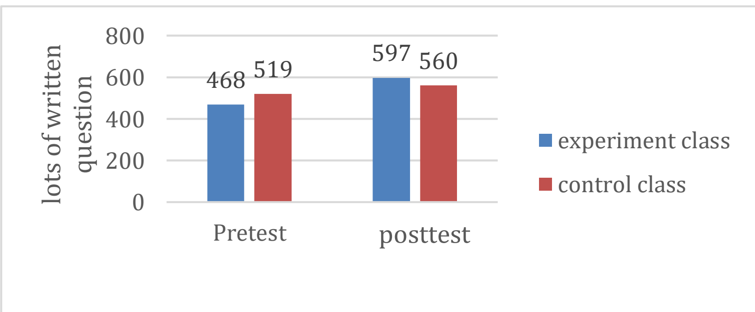

Figure 1. Lots of written questions

Observations on the quantity of oral questions revealed significant differences between the experimental and control classes. In the experimental class, a total of 15 oral questions were recorded (eight from Class XI-1 and seven from Class X-1), which was more than double the seven oral questions generated by the control class (four from Class XI-2 and three from Class X-2). This disparity in quantity suggests that the learning intervention implemented in the experimental class effectively encouraged students to be more active and confident in posing questions orally in class, aligning with previous

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findings on the general increase in the quantity of questions. The environment designed to facilitate interaction and curiosity clearly impacted the frequency of student questions, aligning with the importance of active student participation in learning (Aryanti et al., 2020). For more details, see Figure 2 below.

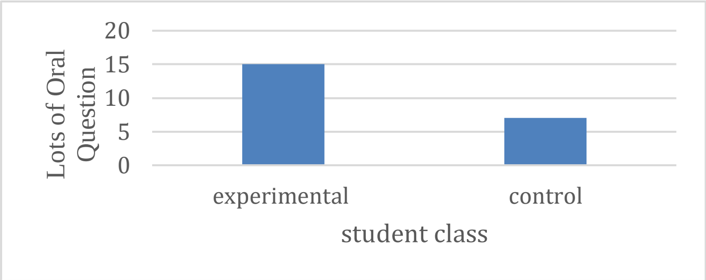

Figure 2. Differences in the increase in the quantity of oral questions

However, when examining the quality of oral questions in terms of cognitive level, both the experimental and control classes exhibited similarly low scores, with average scores of 0.32 and 0.31, respectively. These low scores suggest that most oral questions posed by students in both groups tended to be at lower cognitive levels (e.g., remembering or understanding, according to Bloom's Taxonomy). This finding is consistent with previous studies, which often report that students tend to ask questions at basic cognitive levels, regardless of the type of intervention (Salamah et al., 2022; Pramudiyanti et al., 2019). Although the intervention successfully increased the quantity of oral questions, its impact on enhancing the cognitive level of these questions might necessitate a longer intervention duration or more intensive, specific strategies to stimulate higher order thinking in spontaneous questioning. For more details, see Figure 3 below.

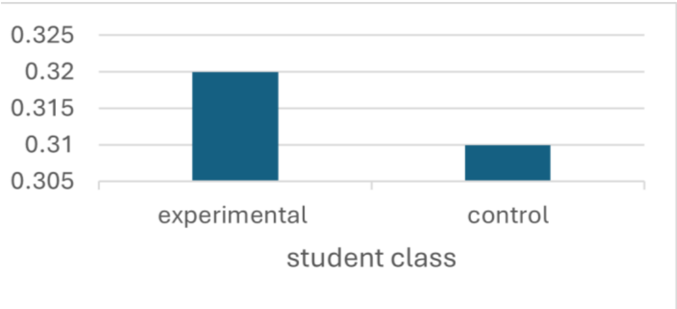

Figure 3. Differences in the quality of oral questions based on cognitive level

Interestingly, despite the low cognitive levels, the quality of oral questions in terms of effectiveness yielded high results for both groups (experimental class with a score of 0.77 and control class with a score of 0.79). Question effectiveness refers to aspects such as conciseness, clarity, focus, and the ability to elicit information (Hafizo et al., 2022). High scores in effectiveness indicate that, even if students' questions were not always at a high thinking level, they were able to formulate clear, focused, and relevant questions within the context of the discussion or material. This is crucial because practical, albeit simple, questions still facilitate classroom communication and clarification and can help students integrate old knowledge with new information, deepening understanding and long-term memory (Pramudiyanti et al., 2019; Muliati et al., 2023). This may reflect students' basic communication skills or a classroom environment that encourages structured questioning, even if it has not yet reached the desired cognitive depth. For more details, see Figure 4 below.

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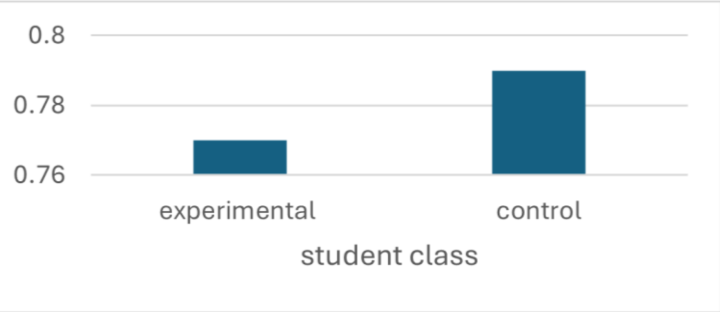

Figure 4. Differences in the quality of oral questions based on the effectiveness of the questions

Based on the analysis of the independent sample t-test on the gain score of students' questioning ability (referring to the total quality score from written tests/compilations), a significant difference in improvement was found between the experimental and control groups ($p<0.001$). This result was supported by the fulfillment of normality assumptions for the gain score data (Shapiro-Wilk, $p = 0.130$) and homogeneity of variances (Levene's, $p = 0.067$). For a more detailed understanding of the statistical test results, please refer to Tables 3, 4, and 5.

Table 3. Assumption Checks

Test of Normality (Shapiro-Wilk)			*Test of Equality of Variances (Levene's)*				
Residuals	W	p		F	df_1	df_2	p
N-gain score	0.977	0.130	N-gain skor	3.456	1	82	0.067

Note. Significant results suggest a deviation from normality.

Table 4. Descriptives

Group Descriptives

	Group	N	Mean	SD	SE	Coefficient of variation
N-gain skor	1	41	13.244	11.245	1.756	0.849
	2	43	2.581	8.166	1.245	3.163

Table 5. Independent Samples T-Test

	t	df	p	Cohen's d	SE Cohen's d
N-gain score	4.990	82	< .001	1.089	0.249

Note. Student's t-test.

A Cohen's d value of 1.089 indicates a large effect size of the intervention. This means that the learning intervention applied in the experimental class not only resulted in a statistically significant improvement in questioning ability but also produced a very substantial and practically meaningful increase compared to the control group. In other words, students in the experimental class demonstrated significantly superior improvement in questioning ability compared to those in the control class, who received conventional instruction. This finding is consistent with the literature, which states that questioning ability is a fundamental cognitive skill that sparks curiosity and fosters deep understanding (Indriyani & Rohita, 2019) and is crucial for developing critical thinking (Salamah et al., 2022).

Although the independent t-test previously indicated that both groups (experimental and control) showed significant internal improvement from pre-test to post-test, the results of the independent t-test on gain scores definitively confirmed that the improvement experienced by the experimental group was far superior and directly attributable to the intervention. To further illustrate the impact on written questioning ability, the following is an example of a written question from the same student in the experimental class, demonstrating a significant shift in cognitive level.

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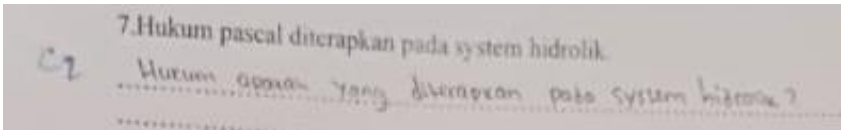

Figure 5. students' written questions in the pre-test

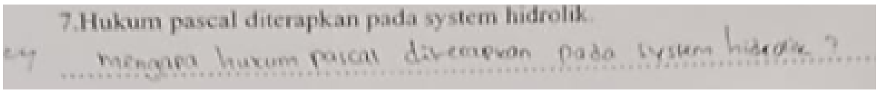

Figure 6. Students' written questions in the post-test

Figure 5 shows that in the pretest, the student's written question was: "What law is used in hydraulic systems?" This question represents a C1 (remembering/knowledge) cognitive level. In contrast, during the post-test in Figure 6, the same student formulated the written question: "Why does a hydraulic system apply Pascal's law?" This indicates a C4 (analyzing) cognitive level, requiring deeper analysis to answer.

The teaching and learning process implemented an integrated learning intervention to develop students' questioning ability, utilizing the problem-based learning (PBL) model, teacher-student question-and-answer interactions, group discussions, and inter-student question-and-answer sessions, as further explained below.

Figure 7. Question and answer interaction between students and teachers

Teacher-student question-and-answer interactions, as illustrated in Figure 7, play a fundamental role in fostering questioning abilities. In this scenario, the teacher is not only an information provider but also an active facilitator who encourages students to formulate their own questions. The environment created allows students to test their understanding, clarify confusion, and delve deeper into the subject matter. This interactive process aligns perfectly with constructivist theory, where students actively build their knowledge through dialogue and direct feedback.

Figure 8. Discussion (collaboration) between students

Furthermore, collaborative discussions among students, as illustrated in Figure 8, serve as a crucial arena for developing critical thinking and questioning skills. When students interact in groups to

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solve problems or understand concepts, they encounter diverse perspectives and levels of comprehension. This process naturally prompts questions to one another—whether to seek clarification, challenge ideas, or build shared understanding. This collaborative aspect strongly reflects social-cognitive theory, where social interaction and observation play a crucial role in shaping cognitive skills. Students learn from questions posed by peers, observe effective questioning strategies, and practice formulating their own questions within a supportive peer context.

Figure 9. Q&A session between student groups

Finally, inter-group question-and-answer sessions, as shown in Figure 9, represent the culmination of efforts to enhance questioning ability. In this format, students are not only responsible for their own understanding but are also expected to articulate questions that challenge other groups or deepen the discussion. This demands a higher level of thinking, as questions must be focused, relevant, and often probing. This mechanism directly supports the development of higher-order cognitive skills, as explained by cognitive theory, which emphasizes how internal mental processes influence the ability to think critically and question. The cognitive level of student questions during these Q&A sessions is further presented in Table 6.

Table 6. Cognitive level during the question-and-answer session between presentation groups

Cognitive level	Quantity of oral questions	Questioner's student code
C1	-	
C2	2	S11, S8
C3	2	S14,S23
C4	4	S2,S5,S17,S28
C5	2	S9,S16
C6	-	

Table 6 shows four oral questions at the C4 cognitive level and two oral questions at the C5 cognitive level, which are categorized as higher-order thinking (HOT) questions. This is attributed to the dynamic exchange of ideas facilitated by the learning environment, which significantly encourages students to move beyond low-level questions and begin posing questions that drive analysis, synthesis, and evaluation, ultimately strengthening their conceptual understanding in physics learning.

These results align with learning theories supporting constructivist and social-cognitive approaches. Constructivist theory emphasizes that students actively construct knowledge through interaction with their environment, where questioning ability serves as a key instrument in this construction process. Meanwhile, cognitive theory indicates how internal mental processes influence questioning ability, and social cognitive theory explains how social interactions and observation within the learning environment shape questioning ability (Yanuardianto, 2019). Active interaction, problem-solving, and an environment that facilitates the exchange of ideas directly contribute to the development of higher-order cognitive skills, such as critical thinking and questioning.

CONCLUSION

Based on a comprehensive analysis of the quantitative data, this study concludes that the learning intervention implemented in the experimental class had a significant effect on improving students' questioning ability in physics learning compared to conventional instruction in the control class. Several key indicators support this finding.

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First, the analysis of written questioning ability test data clearly demonstrates the high effectiveness of this learning intervention. The experimental class experienced a significant increase in the number of written questions by 27.56% (from 468 to 597 questions), far surpassing the 7.9% increase in the control class (from 519 to 560 questions). Second, the independent t-test results on the gain scores confirmed that the difference in questioning ability improvement between the experimental and control groups was statistically significant ($p<0.001$), with a large effect size (Cohen's $d = 1.089$). This indicates that the learning intervention was significantly more effective in facilitating the development of students' questioning skills compared to conventional teaching methods. Third, observations of oral questions also supported this finding in terms of quantity. The learning intervention successfully increased the frequency of oral questions posed by students in the experimental class significantly compared to the control class. Nevertheless, it is important to note that the cognitive level of oral questions in both groups remained relatively low, indicating that the intervention has not yet effectively encouraged higher-order thinking questions. However, the quality of oral questions, in terms of effectiveness (clarity and focus), remained high in both groups, indicating that students were able to formulate informative and relevant questions, even if they were not cognitively complex.

This study makes important contributions to the physics education literature by demonstrating the effectiveness of a problem-based learning model combined with structured teacher-student question-and-answer interactions, collaborative group discussions, and inter-group Q&A sessions in enhancing students' questioning initiative and quantity. The findings also highlight that while the intervention can increase the frequency and effectiveness of questions, improving the cognitive quality of oral questions might require more specific strategies or a longer intervention duration. The practical implication is that physics teachers can adopt this teaching methodology to foster more active student participation and gradually develop their questioning skills.

This study has several limitations. First, the relatively short duration of the intervention (one week) might limit the ability to observe more profound changes in the higher-order cognitive quality of questions. Second, the focus on a single school and a specific physics subject might limit the generalizability of the findings to broader contexts. Third, although oral observation data were collected, the overall quantity of oral questions was still relatively small compared to written questions, which may affect the strength of the quality analysis.

Based on the findings and limitations of this study, it is recommended that future research be conducted with a longer intervention duration, perhaps involving multiple learning cycles or implementation over a semester, to explore the potential for improving the quality of questions at higher cognitive levels. Additionally, future research could consider the use of more explicit scaffolding techniques or specific training to stimulate higher-order questions. It is also suggested that this study be replicated in other schools or educational levels, as well as in different subject matters, to test the generalizability of the intervention's effectiveness.

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