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Enhancing Problem-Solving Abilities and Science Process Skills through Guided Inquiry with Laboratory Media in High School

Sunarti Rahman*, Muhammad Syahri, Agus Tinus

Department of Pedagogy, University of Muhammadiyah Malang, Malang, 65144, Indonesia

**Corresponding author: sunartira03@gmail.com*

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Abstract – *Physics education at the high school level continues to face challenges in cultivating students' higher-order thinking, particularly problem-solving ability and science process skills, which are essential for scientific literacy and future learning. Conventional lecture-based approaches often result in passive learning and limited opportunities for inquiry, creating an urgent need for innovative teaching strategies. This study aimed to investigate the effectiveness of guided inquiry supported by laboratory media in enhancing problem-solving ability and science process skills among high school students. Employing a quasi-experimental design with a pretest–posttest nonequivalent control group, the research was conducted with 64 Grade X students at SMAN 1 Gowa, Indonesia, who were divided into an experimental group taught through guided inquiry with laboratory media and a control group receiving traditional instruction. Data were collected using a validated problem-solving test and a science process skills assessment and analyzed using descriptive statistics, independent samples t-tests, and normalized gain (N-gain) scores. The results indicated that the experimental group achieved significantly higher improvements, with N-gain scores of 0.70 (high) for problem-solving and 0.50 (medium) for science process skills, compared with 0.60 and 0.38, respectively, in the control group. These findings confirm that guided inquiry combined with laboratory media provides a more effective learning environment by promoting active engagement, conceptual understanding, and procedural competence. The novelty of this study lies in its focus on the measurement topic in high school physics, an area often associated with analytical difficulty. The study concludes that this instructional model contributes to the advancement of physics education by offering empirical evidence for curriculum innovation and pedagogical reform.*

Keywords: *guided inquiry; laboratory media; physics education; problem-solving ability; science process skills*

I. INTRODUCTION

Physics education at the high school level plays a pivotal role in shaping students' scientific literacy and fostering their ability to understand and interpret the natural world. As a discipline, physics is central not only to the acquisition of fundamental scientific principles but also to the cultivation of analytical reasoning and technological competence. The ability to comprehend physics concepts equips students with the tools to engage critically with scientific phenomena, thereby enhancing their preparedness for higher education and professional careers in science and engineering (Bao & Koenig, 2019; Kotsis, 2024). However, despite its importance, the teaching and learning of physics remain fraught with challenges that impede student progress. A recurring problem is students' persistent struggle with abstract concepts, which often manifests in limited problem-solving capacity and insufficient development of science process skills. This issue is exacerbated by traditional instructional practices that emphasize rote memorization and passive reception of knowledge rather than active engagement and critical thinking (Amirova, 2025; Shrestha et al., 2023). These limitations necessitate pedagogical reform, where teaching methods should not only transmit factual knowledge but also foster higher-order thinking and inquiry competencies aligned with the demands of 21st-century education (Almulla, 2023).

Recent scholarship has increasingly advocated for inquiry-based learning (IBL) as a transformative pedagogical framework capable of addressing these challenges. Rooted in constructivist learning theory, IBL shifts the focus from teacher-centered transmission of information to student-centered exploration and investigation, thereby cultivating deeper conceptual understanding, critical reasoning, and creativity. Within the spectrum of inquiry approaches, guided inquiry has attracted particular attention for its balanced provision of teacher support and learner autonomy (Ramnarain & Rudzirai, 2020). Unlike open inquiry, which can overwhelm students with limited prior knowledge, guided inquiry scaffolds the learning process by providing structured tasks and guidance while still allowing learners to develop investigative and analytical skills. Moreover, the integration of laboratory media within guided inquiry contexts has been shown to enhance experiential learning by allowing students to conduct hands-on experiments, thereby linking theoretical content with real-world applications (Shi et al., 2025; Buchberger & Mill, 2025). These combined pedagogical elements have the potential to create dynamic learning environments that actively engage students in scientific inquiry and promote transferable skills essential for academic and professional success.

Despite the well-documented benefits of inquiry-based learning, conventional teaching methods continue to dominate in many high schools, especially in physics education. Teacher-centered instruction, characterized by lecture-driven delivery, still represents the prevailing mode of classroom practice. This approach, while efficient in covering curricula, often fails to develop problem-solving skills and science process competencies that are critical for meaningful learning (Taasoobshirazi & Carr, 2008). Students under such methods frequently demonstrate difficulty in transferring theoretical knowledge to novel contexts and struggle with tasks that require analysis, synthesis, and evaluation. These deficiencies pose serious challenges to preparing students for scientific literacy and the demands of the modern workforce. In response, scholars have argued for the implementation of inquiry-oriented pedagogies as an alternative that can address these shortcomings (Rasa et al., 2025). By engaging students in active problem identification, hypothesis testing, experimentation, and data analysis, inquiry-based approaches are believed to foster both problem-solving ability and scientific reasoning.

The core research problem in this context lies in determining the extent to which guided inquiry, when integrated with laboratory media, can effectively improve students' competencies in problem-solving and science process skills. Prior studies have emphasized the significance of these competencies as foundational elements of scientific literacy, underscoring their role in enabling learners to navigate complex scientific problems (Kumar & Acharya, 2024). Nevertheless, the dominance of traditional pedagogy in high school physics has led to persistent gaps in these skill areas. While process-oriented and inquiry-based approaches have been proposed, their implementation in real classroom settings remains limited, particularly in resource-constrained environments. Addressing this problem requires empirical investigation of pedagogical models that combine theoretical frameworks of inquiry with practical tools, such as laboratory media, that enhance experiential engagement.

Several studies have proposed guided inquiry as a specific solution to these pedagogical challenges, emphasizing its potential to transform the learning experience in science classrooms. Guided inquiry encourages students to pose questions, investigate phenomena, and construct knowledge under the facilitation of teachers, thereby bridging the gap between structured instruction and independent discovery (Dobber et al., 2017; van Uum et al., 2017). Empirical evidence suggests that such approaches significantly enhance students' critical thinking and cognitive engagement, leading to measurable improvements in problem-solving ability (Alkhatib, 2019). Furthermore, the incorporation of laboratory media into guided inquiry has been shown to enrich the learning environment by providing tangible experiences of scientific concepts. Mahmud et al. (2025) demonstrated that interactive laboratory-based activities stimulate learner engagement and support the development of cognitive and metacognitive skills. Laboratory tools enable students to conduct authentic experiments, observe real-time outcomes, and make informed decisions based on empirical data, which aligns closely with the epistemic practices of scientists. This integration of inquiry pedagogy with laboratory media thus offers a promising pathway for addressing the limitations of conventional physics education.

The literature has also highlighted how guided inquiry and laboratory experiences collectively foster science process skills, including observation, measurement, hypothesis formulation, data collection, and interpretation. Such skills are indispensable for scientific inquiry and provide the foundation upon which higher-order problem-solving is built. Research by Chiu et al. (2015) and Cairns (2019) confirmed that engaging students in laboratory-based inquiry strengthens their ability to connect theoretical principles with empirical evidence, thereby enhancing both conceptual understanding and scientific reasoning. Moreover, studies in different educational contexts have demonstrated that guided inquiry promotes active learning, critical reflection, and collaboration, which are essential for developing students' capacity to address complex scientific challenges (Setiyawati & Kuswanto, 2015; Hofstein & Lunetta, 2004). Nevertheless, despite the growing body of evidence, few studies have directly examined the combined effect of guided inquiry and laboratory media in the context of high school physics, particularly in domains such as measurement, which are known for their conceptual and analytical difficulties (Chengere et al., 2025). This underexplored area represents a significant gap in the literature that warrants focused investigation.

Building upon these insights, the present study aims to evaluate the effects of guided inquiry supported by laboratory media on students' problem-solving abilities and science process skills in physics. Unlike prior research that has either examined inquiry-based approaches in general or explored laboratory interventions in isolation, this study integrates the two, thereby offering a more comprehensive model of pedagogical innovation. The novelty of this study lies in its specific focus on high school physics education within the domain of measurement, where students often encounter persistent challenges in applying theoretical knowledge to practical and analytical tasks. By situating guided inquiry within a laboratory context, the research seeks to provide empirical evidence of its efficacy in enhancing both cognitive and procedural competencies. In doing so, the study not only addresses a critical gap in the literature but also contributes to ongoing discussions on curriculum innovation and pedagogical reform in science education.

II. METHODS

This study employed a quasi-experimental design to examine the effectiveness of guided inquiry with laboratory media in enhancing high school students' problem-solving abilities and science process skills in physics. The methodological framework was grounded in established practices in educational research, where quasi-experiments are widely used to assess the impact of instructional interventions when random assignment is not feasible (Gopalan et al., 2020). Such designs provide robust evidence of causal inference by enabling researchers to compare learning outcomes across groups exposed to different teaching strategies. In this case, one group received guided inquiry instruction supported by laboratory media, while the other was taught using conventional lecture-based methods. The research followed a pretest–posttest nonequivalent control group design, allowing the evaluation of changes in student competencies before and after the intervention (Choenarom & Samputtanon, 2025).

The study was conducted at SMAN 1 Gowa, a public high school in South Sulawesi, Indonesia. The setting was selected due to its diverse student population and willingness to engage in experimental pedagogy. The population consisted of all Grade X students, from which two classes were chosen as samples. Each class comprised 32 students, making a total of 64 participants. One class was designated as the experimental group and received guided inquiry instruction with laboratory media, while the other class served as the control group and followed conventional instruction. The assignment of classes was randomized to reduce potential selection bias, ensuring the comparability of groups at the start of the study (Higgins et al., 2019). Importantly, the classes were relatively homogeneous in academic performance, as placement was based on general academic criteria rather than ability tracking, thereby strengthening the internal validity of the study.

The independent variable in this research was the instructional approach, with two conditions: guided inquiry with laboratory media and traditional teacher-centered instruction. Guided inquiry was operationalized as an instructional method where the teacher facilitated student learning through structured investigations, scaffolding their engagement with scientific concepts, and prompting them to pose questions, design experiments, and analyze results (van Uum et al., 2017). Laboratory media referred to the utilization of physical instruments such as rulers, thermometers, and stopwatches to support students' hands-on engagement with measurement tasks, thereby linking theoretical knowledge to empirical practice (May et al., 2023). The dependent variables were students' problem-solving abilities and science process skills. Problem-solving ability was defined as the capacity to identify, analyze, and resolve physics-related problems. At the same time, science process skills encompassed competencies such as observing, hypothesizing, experimenting, collecting data, and interpreting results (Salumita & Putranta, 2025).

Two instruments were employed to measure these dependent variables: a problem-solving test and a science process skills assessment. The problem-solving test consisted of both multiple-choice and short-answer questions related to measurement in physics, designed to evaluate students' ability to apply concepts to practical contexts. The science process skills assessment required students to engage in inquiry-based tasks, demonstrating their ability to formulate hypotheses, design and conduct experiments, analyze data, and draw conclusions. Both instruments underwent rigorous validation by a panel of experts, including physics teachers and university faculty, to ensure content validity and alignment with curricular objectives. Reliability was confirmed through Cronbach's alpha, with a coefficient above 0.70, meeting the threshold for educational research instruments (van Uum et al., 2017).

The procedure of data collection was implemented in three stages: pretesting, intervention, and posttesting. At the beginning of the study, all participants completed a pretest to establish baseline measures of problem-solving ability and science process skills. This ensured that any subsequent differences could be attributed to the instructional approach rather than pre-existing disparities. Following the pretest, the experimental group received instruction through guided inquiry with laboratory media. The teaching sequence was structured around the topic of physics measurement. Students were encouraged to engage with laboratory tools in hands-on experiments while being guided through each stage of the inquiry cycle. Teachers posed questions, facilitated peer discussion, and provided feedback throughout the process, consistent with the principles of scaffolding and guided discovery. In contrast, the control group was taught through conventional teacher-centered lectures and textbook-based exercises, emphasizing theoretical exposition without the use of laboratory experimentation. After the intervention, both groups were administered the posttest, identical in format to the pretest, to measure changes in student competencies.

Data analysis followed both descriptive and inferential statistical techniques. Descriptive statistics, including means, standard deviations, and frequencies, were used to summarize the performance of both groups on the pretest and posttest. This analysis provided an overview of learning outcomes and allowed for preliminary comparisons between groups (Leiva-Candia et al., 2022). To formally test the hypotheses, inferential statistics were conducted using independent samples t-tests to compare the mean posttest scores of the experimental and control groups. The t-test is particularly appropriate in this context as it identifies whether observed differences between groups are statistically significant (Dankel & Loenneke, 2021). A significance threshold of $p < 0.05$ was applied to determine whether the intervention had a meaningful effect.

In addition to t-tests, normalized gain (N-gain) analysis was conducted to measure the effectiveness of the intervention relative to the maximum possible improvement. The N-gain index, introduced by Hake and widely used in physics education research, provides a standardized measure of learning gains by comparing the difference between pretest and posttest scores against the maximum achievable score (Triyono et al., 2024). The classification of N-gain values into low, medium, and high categories allowed the interpretation of the magnitude of learning improvement in both groups. In this study, the N-gain served as a complementary measure to the t-tests, providing insights into the practical effectiveness of guided inquiry with laboratory media.

To provide a clearer overview of the methodological framework, the structure of this study is illustrated in Figure 1.

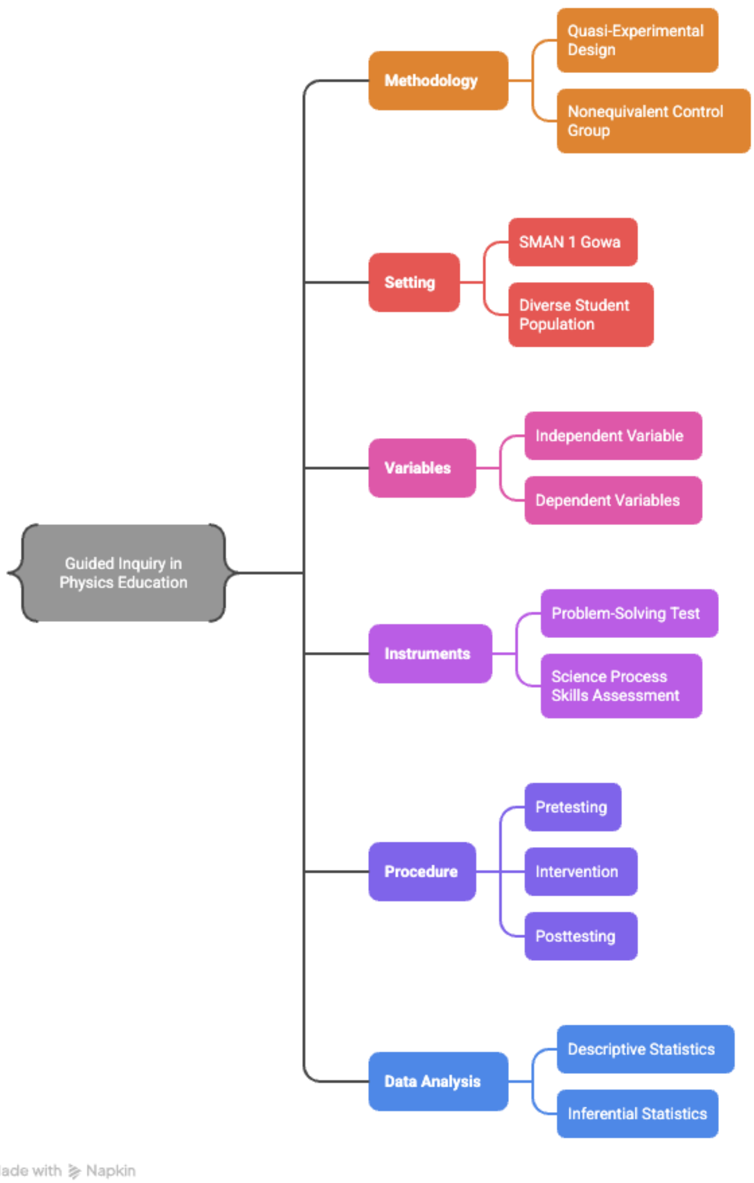

Figure 1. Research methodology of the study on guided inquiry in physics education

III. RESULTS AND DISCUSSION

The findings of this study are presented in accordance with the research objectives, namely, to evaluate the impact of guided inquiry supported by laboratory media on students' problem-solving abilities and science process skills. The results are reported through descriptive statistics, inferential analyses, and N-gain scores to provide a comprehensive picture of student learning outcomes. Comparisons between the experimental and control groups are emphasized in order to highlight the relative effectiveness of the intervention.

3.1 Problem-solving ability

The descriptive analysis highlighted clear differences between the two groups in terms of problem-solving performance. Table 1 presents the mean scores, standard deviations, and N-gain values before and after the intervention.

Table 1. Descriptive statistics for problem-solving ability scores

Group	Pretest mean	Pretest SD	Posttest mean	Posttest SD	N-Gain
Experimental	15.97	5.08	74.93	10.37	0.70
Control	15.67	5.55	66.23	9.94	0.60

The experimental group showed substantial improvement, increasing from a mean pretest score of 15.97 (SD = 5.08) to a posttest mean of 74.93 (SD = 10.37). The corresponding N-gain of 0.70 was classified as high. In comparison, the control group improved from 15.67 (SD = 5.55) to 66.23 (SD = 9.94), with an N-gain of 0.60, which falls within the medium category. These findings suggest that guided inquiry with laboratory media produced stronger gains in problem-solving ability than conventional lecture-based instruction. The higher N-gain in the experimental group indicates that the intervention was more effective in enabling students to bridge the gap between pre-existing knowledge and post-intervention competencies.

3.2 Science process skills

Descriptive statistics also demonstrated meaningful improvements in science process skills. Table 2 summarizes the pretest and posttest means, standard deviations, and N-gain values for both groups.

Table 2 Descriptive statistics for science process skills scores

Group	Pretest mean	Pretest SD	Posttest mean	Posttest SD	N-Gain
Experimental	67.97	3.41	85.67	4.60	0.50
Control	67.83	4.81	80.23	5.94	0.38

The experimental group improved from a pretest mean of 67.97 (SD = 3.41) to 85.67 (SD = 4.60) in the posttest, yielding an N-gain of 0.50, categorized as medium. The control group also improved, but less markedly, from 67.83 (SD = 4.81) to 80.23 (SD = 5.94), with an N-gain of 0.38, also within the medium range. These results indicate that while both groups showed progress, the experimental group achieved greater gains, confirming that guided inquiry supported by laboratory media enhanced the development of science process skills more effectively than traditional instruction. The higher N-gain suggests that the experimental group was better able to internalize procedural skills such as observation, measurement, and data interpretation.

3.3 Inferential analysis of problem-solving ability

To verify whether the differences observed in problem-solving ability were statistically significant, an independent samples t-test was conducted. The results are shown in Table 3.

Table 3. Independent samples T-Test for problem-solving ability

Group	t-value	df	Sig. (2-tailed)	Mean difference	Std. Error difference
Problem-solving	-23.364	58	0.000	-40.40	1.73

As shown in Table 3, the t-test for problem-solving ability yielded a t-value of -23.364, with 58 degrees of freedom, and a significance level of 0.000 ($p < 0.05$). This result indicates that there was a statistically significant difference in the problem-solving ability scores between the experimental and control groups. The experimental group, which received guided inquiry with laboratory media, outperformed the control group, providing strong evidence that the intervention positively affected students' problem-solving skills.

3.4 Inferential analysis of science process skills

Similarly, an independent samples t-test was conducted to assess the statistical significance of the difference in science process skills between the experimental and control groups. The results of this analysis are presented in Table 4**.**

Table 4. Independent samples T-Test for science process skills

Group	t-value	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Science Process Skills	-9.031	58	0.000	-10.47	1.16

Table 4 shows that the t-test for science process skills yielded a t-value of -9.031, with 58 degrees of freedom, and a significance level of 0.000 ($p < 0.05$). This result indicates a statistically significant difference between the two groups, with the experimental group showing a higher mean score for science process skills after the intervention. The mean difference between the experimental and control groups was -10.47, further confirming the superior effect of guided inquiry with laboratory media on students' science process skills.

The findings of this study demonstrate that guided inquiry supported by laboratory media significantly improved both problem-solving ability and science process skills among high school students compared with conventional instruction. These results corroborate earlier evidence suggesting that inquiry-based pedagogies play a vital role in fostering critical engagement and deeper understanding in science education (Dobber et al., 2017; Ramnarain & Rudzirai, 2020). The experimental group's higher N-gain in problem-solving ability (0.70) and superior performance in science process skills (N-gain = 0.50) highlight the capacity of guided inquiry to address enduring weaknesses in physics learning, particularly the challenges students face in dealing with abstract and analytical tasks (Shrestha et al., 2023; Kotsis, 2024). These outcomes strengthen the case for integrating guided inquiry with laboratory experiences as a means of transforming the teaching of physics into an active, student-centered process.

One of the key implications of the results lies in their support for the argument that traditional lecture-based instruction does not adequately cultivate higher-order thinking or problem-solving competencies. While conventional teaching may transmit theoretical knowledge efficiently, it often fails to create opportunities for students to apply this knowledge in authentic contexts (Taasoobshirazi & Carr, 2008). The performance of the control group in this study, although showing improvement, remained significantly lower than that of the experimental group, reinforcing the limitations of teacher-centered pedagogy. This finding is aligned with critiques in the literature emphasizing that passive learning approaches restrict students' ability to develop critical reasoning and independent inquiry skills (Amirova, 2025; Almulla, 2023). The results of this study, therefore, provide empirical justification for shifting toward more interactive pedagogical strategies in physics education.

The improvement in problem-solving ability among the experimental group can be attributed to the iterative and exploratory nature of guided inquiry. Students engaged actively in hypothesis formulation, experimentation, and evaluation of evidence, processes that foster cognitive engagement and encourage systematic approaches to complex tasks (Tachie, 2019). These findings resonate with research demonstrating that inquiry-based methods cultivate analytical reasoning by requiring learners to navigate uncertainty and develop solutions based on empirical evidence (Arifin et al., 2025). The inclusion of laboratory media in the instructional design amplified this effect by bridging the gap between abstract theoretical concepts and practical applications. When students manipulated laboratory tools such as rulers, stopwatches, and thermometers, they were able to confront real measurement challenges, thereby contextualizing their learning. This hands-on engagement reinforces existing studies suggesting that laboratory activities significantly enhance conceptual retention and problem-solving competence by situating knowledge within authentic experiences (Vorsah & Oginni, 2025; Buchberger & Mill, 2025).

The results for science process skills further confirm the benefits of guided inquiry supported by laboratory media. Students in the experimental group not only improved their ability to observe and measure but also demonstrated enhanced proficiency in formulating hypotheses, designing experiments, and interpreting data. These competencies are essential for scientific inquiry and represent core components of scientific literacy (Windschitl et al., 2008). The results align with previous findings indicating that inquiry-oriented pedagogy provides students with opportunities to practice authentic scientific processes, which, in turn, strengthen their understanding of the nature of science (Setiyawati & Kuswanto, 2015; Hofstein & Lunetta, 2004). In particular, the use of laboratory media enabled students to engage directly with physical phenomena, thereby connecting theoretical knowledge to empirical verification. Similar to the conclusions of Chiu et al. (2015) and Cairns (2019), this study demonstrates that experiential, hands-on learning environments foster a deeper integration of science process skills, highlighting the irreplaceable role of laboratory experiences in science education.

The statistical significance of the differences between the experimental and control groups adds robustness to these conclusions. The independent samples t-test results, which showed p-values below 0.001 for both problem-solving ability and science process skills, provide strong evidence that the observed improvements were not due to chance but rather the result of the instructional intervention. This is particularly relevant given concerns about the generalizability of quasi-experimental designs, where random assignment is not always possible (Gopalan et al., 2020). By demonstrating significant effects despite these constraints, the study contributes valuable empirical evidence to the growing body of research advocating for inquiry-based and laboratory-supported instruction in secondary education contexts (Chengere et al., 2025; Mahmud et al., 2025).

Furthermore, the findings of this study contribute to ongoing debates about the optimal balance between guidance and autonomy in inquiry-based learning. Excessive openness in inquiry can overwhelm learners, particularly those with limited prior knowledge, while overly rigid structures can limit opportunities for authentic exploration (van Uum et al., 2017). Guided inquiry provides an effective middle ground, where students are given sufficient scaffolding to structure their investigations while retaining the autonomy to explore and discover. The strong outcomes observed in this study validate this balance, suggesting that guided inquiry can provide both direction and freedom in ways that enhance learning outcomes. This echoes the perspectives of Huang (2022), who argued that inquiry-based laboratories significantly enhance teamwork, problem-solving, and student attitudes when appropriately scaffolded.

The study also extends prior work by situating its investigation in the domain of measurement within high school physics. Measurement is a fundamental yet conceptually demanding topic, often associated with errors, abstraction, and analytical difficulty. By focusing on this domain, the research addresses a critical gap in the literature, as few prior studies have explored the integration of guided inquiry and laboratory media in this specific context. The positive results observed suggest that guided inquiry is particularly effective in domains where abstract concepts can be concretized through experimentation, offering practical insights for curriculum innovation. These findings resonate with calls for physics education reform to place greater emphasis on conceptual understanding and practical engagement rather than rote memorization (Bao & Koenig, 2019).

Despite its contributions, the study is not without limitations. Conducting the research in a single school context restricts the generalizability of the results, as variations in school culture, resources, and teacher expertise could influence outcomes. Additionally, while quasi-experimental designs offer valuable insights, they cannot completely rule out pre-existing differences between groups. Nonetheless, the relatively homogenous background of the sample and the use of pretest scores to establish baseline equivalence mitigate some of these concerns (Higgins et al., 2019). Future research should therefore expand the scope of inquiry by including diverse educational settings and employing randomized controlled trials where feasible to strengthen the external validity of findings.

IV. CONCLUSION AND SUGGESTION

The results of this study provide clear evidence that guided inquiry supported by laboratory media significantly enhances students' problem-solving abilities and science process skills in high school physics. The experimental group consistently outperformed the control group, with higher posttest means and stronger N-gain values in both domains. Statistical analyses further confirmed that these differences were significant, demonstrating that the intervention effectively fostered deeper cognitive engagement, practical application of concepts, and stronger development of essential scientific skills compared with conventional instruction.

Despite the robust findings, this study has certain limitations. It was conducted in a single school with a relatively small sample, which may restrict the generalizability of the results to other contexts. In addition, the quasi-experimental design, while appropriate for classroom-based research, cannot fully eliminate potential confounding variables. Future research should therefore consider involving larger and more diverse populations across multiple schools, as well as employing randomized controlled trials to strengthen external validity. Further studies could also investigate the long-term effects of guided inquiry on knowledge retention, attitudes toward science, and transferability of skills to other disciplines. The contribution of this study lies in providing empirical evidence that integrating guided inquiry with laboratory media can transform physics instruction by promoting active learning and scientific inquiry, offering both theoretical insights and practical guidance for improving the quality of physics education.

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