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The Effect of STEM Integrated *Guided inquiry* Learning Model on *Problem solving Skills* of Grade 8 Students on Vibration Material and Waves

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Abstract: In the 21st century, students are required to possess problem-solving skills, this is because students' problem-solving skills are closely related to real-life issues. However, in reality, students' problem-solving abilities in Indonesia are still very low. This has been demonstrated by research conducted by PISA and TIMSS. The primary objective of this study is to evaluate the impact of implementing a guided inquiry learning model integrated with STEM on problem-solving skills, specifically in the subject of vibrations and waves. This study uses a quasi-experimental pretest-posttest design with a control group to test the effectiveness of the intervention. The study involved two classes with different treatments as samples: the control class, which did not receive the intervention, and the experimental class, which receive the intervention, with 30 students in each class. Data analysis testing was conducted using the Shapiro-Wilk normality test, homogeneity test, independent sample t-test, and N-Gain test. The research data analysis revealed an improvement in problem-solving skills in the theory of vibrations and waves through the application of the guided inquiry model integrated with STEM. This is evident based on the independent sample t-test with a Sig.value is 0.000 ($p < 0.005$), leading to the conclusion that the guided inquiry learning model integrated with STEM significantly affects the problem-solving abilities of 8th-grade students in the topic of vibrations and waves.

Keywords: guided inquiry, STEM, problem solving skills, vibration and wave

▪ INTRODUCTION

Natural Science (IPA) is a field of study that delves into natural phenomena and all aspects of nature. Natural Science employs systematic methods involving critical thinking and curiosity to investigate natural phenomena. This process includes steps such as observation, measurement, formulation and testing of hypotheses, information gathering, experimentation, and prediction (Purbosari, 2016). The learning process in Natural Science is closely tied to activities such as observing, understanding, and analyzing problems so that the acquired knowledge can be applied to real-life situations. However, the education process for Natural Science in most schools still heavily relies on rote memorization of concepts, whereas Natural Science learning should emphasize skills in processes, ideas, problem-solving, and fostering students' curiosity (Oktaviani & Tari, 2018).

In the modern era, Natural Science (IPA) is closely related to real-life issues (Cahyani & Setyawati, 2016). Physics is one of the branches of Natural Science that is fundamental for students to understand the natural phenomena occurring around them (Maison et al., 2021). The National Curriculum implicitly emphasizes the importance of applying physics concepts in daily life and technology as part of the basic competencies in physics. The relationship between natural phenomena and technological utilization is a relevant aspect in enhancing students' scientific literacy. Therefore, education should

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focus on developing students' knowledge, skills, and social attitudes to prepare them for global competition (Saputro et al., 2023).

Problem-solving skills are essential for students as they are useful for application in real-life contexts. This is further elaborated in research by Saputro et al., (2023), which highlights the fact that everyone will encounter various problems that need to be addressed. According to Polya (1973), there are four stages of problem solving: understanding the problem, planning the solution, implementing the plan, and reviewing the results obtained. Problem-solving skills teach students to independently discover concepts that are holistic, meaningful, authentic, and applicable (Sumiantari et al., 2019). These skills are a core competency that physics education seeks to develop, which is closely linked to Natural Science (Docktor et al., 2015).

The reality in the field reveals that in physics learning, which is a branch of Natural Science, students' problem-solving skills are still relatively low. Students encounter challenges when faced with problem-solving tasks related to key Natural Science concepts. One of the obstacles students face in solving problems is their tendency to rely solely on memorizing concepts, which makes it difficult for them to connect Natural Science concepts with real-life situations and problems (Sulistiowati, 2022). This aligns with the data presented by the OECD (2024) and (Martin et al., 2015).

An optimal learning model stimulates students' initiative for independent learning and encourages them to develop their own understanding through investigation and exploration. Innovative teaching, designed by educators acting as facilitators, enables students to thrive during the learning process and achieve desirable outcomes. This strategy is aimed at creating a positive learning environment to achieve the expected learning objectives (Hapsari & Fatimah, 2021). Inquiry-based learning, rooted in the constructivist approach, helps students build knowledge similar to how scientists do (Maknun, 2020). The inquiry model positions students at the center of active, inquiry-based learning. In this model, students are not only presented with knowledge and facts but are also encouraged to develop critical and creative thinking skills (Dhanil et al., 2024).

Guided inquiry is one of the learning models considered relevant to support education in today's context (Ristanti et al., 2023). According to a study implemented by Maharani et al. (2020), the application of guided inquiry significantly impacts student's science process skills and learning outcomes. This aligns with research by Dewanto et al., (2024), which explains that the Guided Inquiry Model is an effective approach to fostering students' creative thinking skills in science education. This effectiveness is attributed to its focus on training students to actively discover concepts or theories independently, while still receiving guidance from teachers. Research conducted by Lewa et al. (2018) further reveals that the application of the guided inquiry model successfully improves students' problem-solving abilities. This finding is supported by Mustika et al. (2021), who stated that learning through the guided inquiry model effectively enhances students' problem-solving skills. This effectiveness arises because the guided inquiry approach encourages students to actively engage during the knowledge acquisition process and independently discover new knowledge. Through this approach, students are able to understand concepts more deeply and develop stronger problem-solving skills.

The application of the guided inquiry learning model offers several advantages, including the balanced development of cognitive, affective, and psychomotor dimensions, as it involves all aspects of student growth. Alongside dimension development, this model provides flexibility to accommodate the diverse learning styles of individual students. Internally, it fosters students' enthusiasm for learning, leading them to feel satisfied and motivated by their discoveries. Additionally, it enhances students' intellectual abilities due to their frequent engagement in problem-solving activities, such as gathering and analyzing data independently. This approach also cultivates curiosity, driving students to delve deeper into a given topic.

However, the guided inquiry learning model also has limitations, such as its lack of relevance to real-world contexts (Paramita et al., 2021). Students often struggle to apply conceptual knowledge to accurately explain scientific phenomena. This aligns with research conducted by Sutoyo et al., (2019) which identified several drawbacks of the model, including students' inactivity when placed in heterogeneous groups, the lack of real-life relevance in the problems presented, and the challenges faced by students accustomed to conventional learning models in motivating themselves and learning independently. Kang & Keinonen (2018) suggested that to increase students’ interest in inquiry-based learning, science must be connected to real-world situations. One way to achieve this is by integrating guided inquiry with approaches that relate the topics studied to real-life issues.

STEM (Science, Technology, Engineering, and Mathematics) is an approach that integrates skills and provides a contextual framework (Stohlmann et al., 2012). Permanasari (2016) also conducted research on a method that connects the disciplines of science, engineering, technology, and mathematics in learning. This integration creates learning experiences that are more connected, focused, meaningful, and relevant for students (Ercan et al., 2016). By incorporating these four disciplines into the learning process, STEM fosters 21st-century skills as its student-centered learning environment provides opportunities for students to build direct understanding through inquiry-based approaches (Syukri et al., 2023). Guided inquiry learning and the STEM approach are considered an ideal combination. STEM provides a robust framework for inquiry-based learning, while inquiry encourages students to actively explore and seek knowledge (Paramita et al., 2021).

The STEM approach combines four disciplines: science, engineering, technology, and mathematics. This approach integrates technology and engineering into mathematical content, resulting in more holistic and meaningful learning (Paramita et al., 2021). Compared to other teaching approaches, STEM stands out for its ability to incorporate elements of science, technology, and engineering into mathematics education. When applied continuously, it can produce students who are critical, innovative, knowledgeable, skilled in solving mathematical equations, and capable of utilizing advanced technology (Anggraini & Huzaifah, 2017). Chien & Lajium (2015) emphasized that combining inquiry-based learning with the STEM approach can yield significant positive impacts. STEM, with its focus on inquiry-based learning, is highly recommended to enhance the effectiveness of inquiry-based education. Integrating guided inquiry with STEM offers two main benefits: concretizing mathematical problems and assisting students during the learning process. This approach is expected to increase students' motivation to learn, thereby positively impacting their problem-solving abilities.

STEM-integrated guided inquiry combines physical activities with structured teacher guidance to facilitate students’ independent discovery of concepts and principles within the learning material. This pedagogical model has been shown to enhance students' problem-solving skills, particularly in the study of vibrations and waves, which are closely interconnected with real-world phenomena (Yennita et al., 2017). The topic of vibrations and waves constitutes a fundamental aspect of the Grade VIII junior high school science curriculum, as it directly relates to various real-life applications. Examples include the vibrations of slit drums, rulers, and gamelan instruments when struck. Furthermore, waves form the basis of modern technological advancements, particularly in medical and communication fields, due to their ability to transmit, capture, and process information. However, this topic is often perceived as complex, as students frequently encounter difficulties in comprehending its conceptual framework (Yulianti & Zhafirah, 2020).

Previous research conducted by TIMSS (Trends in International Mathematics and Science Study) indicated that Indonesian students' problem-solving skills remain relatively low, as evidenced by their low scores on TIMSS assessments. TIMSS is an international assessment designed to measure students' abilities in mathematics and science across participating countries. According to the 2015 TIMSS report, Indonesia scored 397, ranking as the fourth lowest among 64 participating countries. This score placed Indonesia in the "Low Science Benchmark" category (Martin et al., 2015).

The low level of problem-solving skills was further corroborated by the findings of the 2022 PISA (Program for International Student Assessment) study (OECD, 2024). PISA, conducted by the Organization for Economic Co-operation and Development (OECD), is an international survey that evaluates the skills and knowledge of 15-year-old students worldwide. The results revealed that Indonesia ranked 76th out of 79 countries in mathematics, with an average score of 424—significantly below the international average of 477 (OECD, 2024). Indonesian students' limited proficiency in solving PISA tasks, particularly those requiring higher-order thinking skills, is a notable concern. The PISA assessment utilizes a six-level difficulty scale, with Level 1 being the easiest and Level 6 the most challenging. Indonesian students' lack of exposure to high-level PISA tasks contributes to their unfamiliarity with the patterns and strategies needed to solve such problems effectively. This indicates that Indonesian students' problem-solving skills remain inadequate and require substantial improvement.

Previous studies have also explored the underlying causes of this issue by interviewing teachers and students. The findings revealed the following: (1) students tend to be passive in the learning process, showing limited courage to express opinions or ask questions during class; (2) the teaching approaches currently implemented are suboptimal in supporting independent or collaborative inquiry among students; and (3) problem-based learning strategies linked to real-world contexts are still unfamiliar to most students (Ramadhani & Hakim, 2021). Furthermore, the lack of effective teaching practices contributes to the low problem-solving abilities of students. The educational process primarily employs traditional, lecture-based methods that are teacher-centered, limiting opportunities for active student engagement.

Based on the aforementioned data, this study implements the STEM-integrated guided inquiry learning model to encourage students to apply physics principles in solving real-world problems. This learning model is designed to guide students in formulating solutions to relevant issues. The integration of science, technology, engineering, and mathematics within the guided inquiry framework enhances students’ ability to master physics concepts more effectively. Research has shown that students who receive instruction through the STEM-integrated guided inquiry model demonstrate improved conceptual understanding (Nisa et al., 2020).

The hypothesis of this study is that the STEM-integrated guided inquiry learning model has a significant effect on students' problem-solving skills. Thus, the purpose of this research is to examine the impact of the STEM-integrated guided inquiry model on the problem-solving abilities of 8th-grade students in the topic of vibrations and waves. This study is expected to provide advancements in instructional methods to optimize conceptual understanding of vibrations and waves.

▪ METHOD

Participants

This study was conducted at a public junior high school in Malang City during the second semester of the 2023/2024 academic year. The research involved all 8th-grade students in the school as the population. The sample was selected using a random sampling technique, resulting in two classes being chosen as the sample: one experimental class and one control class. Each class consisted of 30 students. The experimental class received an intervention using the STEM-integrated guided inquiry model, while the control class was taught using conventional methods.

Research Design and Procedures

The research method employed in this study is a quasi-experimental approach with a pretest-posttest control group design. The quasi-experimental method aims to determine the causal relationship between two factors by adding or eliminating confounding variables (Abraham & Supriyati, 2022). This study was conducted to investigate whether students' problem-solving skills improve more significantly when learning through the STEM-integrated guided inquiry model compared to those who engage in conventional learning models.

This study uses an experimental design with two groups: an experimental group and a control group. In the initial phase, both groups were given a pretest to assess their baseline conditions before any intervention. The experimental group was then treated with learning through STEM-integrated guided inquiry, while the control group did not receive this treatment. After the intervention, both groups were given a posttest to measure the learning outcomes after the treatment.

The research process began with interviews with science teachers to identify learning needs. The researcher then conducted a needs analysis to determine the focus of the study. Following this, research instruments were developed, including student worksheets (LKPD) and test instruments in the form of pretests and posttests. The developed instruments were then validated by experts. The next phase involved a trial run of the instruments to ensure their quality, followed by testing for reliability and validity. Once the instruments were deemed suitable, the researcher proceeded with data collection through field research. The collected data were then analyzed to produce findings that align with the study's objectives.

Instruments

There are two measurement tools or instruments used to assess students' problem-solving abilities in this study: the measurement instrument and the treatment instrument.

The treatment instrument consists of a teaching module and student worksheets (LKPD) as a guide for the learning process. The teaching modules used in this study are divided into two types: one prepared for the experimental group and one for the control group. Another treatment instrument is the LKPD (student worksheet) which is developed for both research groups: the experimental group using the STEM-integrated guided inquiry learning model syntax. The syntax of the STEM-integrated guided inquiry learning model serves as the foundation for the development of the teaching module and the learning process flow, as shown in Table 1.

Table 1. STEM-Integrated guided inquiry syntax

Guided Inquiry Syntax	Problem Solving Skill Indicators	STEM Aspects
Presenting a question or problem	Understanding the problem	Science
Creating a hypothesis		Science
Designing an experiment	Developing strategies or plans for solving the problem	Technology
Conducting the experiment	Solving the problem according to the established plan	Engeneering
Collecting and analyzing data		Mathematics
Drawing conclusions	Reviewing the answers	Mathematics

The measurement instrument consists of a problem-solving ability test using the topics of vibrations and waves. This test includes a pre-test and post-test on the material of vibrations and waves, consisting of 10 open-ended questions. The problem-solving ability test instrument is the same for both the experimental group and the control group.

Before the research was conducted with the students, the instrument was validated, including content and construct validation. The content validity of the test instrument focused on its alignment with the competency achievement indicators and the use of clear and precise language. This process ensured that each item was relevant to the learning objectives and understandable to the students. Additionally, construct validity was performed to assess students' problem-solving abilities. During the construct validation process, the evaluation was conducted by an expert lecturer. The instrument was then revised based on the feedback from the expert.

After expert validation, empirical validation was carried out on the problem-solving test items with grade IX students who had already been taught the material on vibrations and waves. This empirical validation was used to assess the validity of the questions used as problem-solving instruments. The scores for each indicator of students' problem-solving skills were calculated based on the results obtained from the test trial. The assessment criteria for each indicator are listed in Table 2. Scoring results are interpreted based on predetermined scoring guidelines, as in Table 3.

Table 2. Problem solving skills scoring

Indicators	Score	Details
Understanding the Problem	0	The student does not state what is known or what is being asked.
	1	The student states what is known without stating what is being asked, or vice versa.
	2	The student states what is known and what is being asked, but it is somewhat inaccurate.
	3	The student correctly states what is known and what is being asked.
Planning for Completion	0	The student does not state a plan for solving the problem.
	1	The student states a plan for solving the problem, but it is somewhat inaccurate.
	2	The student states a correct plan for solving the problem.
Implementing the Plan	0	The student does not provide any answer.
	1	The student implements the plan, but the answer is incorrect or only partially correct.
	2	The student implements the plan, with half or most of the answer correct
	3	The student implements the plan completely and correctly.
Evaluating	0	The student does not write a conclusion.
	1	The student makes a conclusion, but it is somewhat inaccurate.
	2	The student makes a correct conclusion.

Table 3. Problem solving skills assessment criteria

Value	Criteria
85.00 – 100	Very Good
70.00 – 84.99	Good
55.00 – 69.99	Simply
40.00 – 54.99	Low
0 – 39.99	Very Low

The next step is to test the validity of the question items to assess the feasibility of the question items based on the data obtained from the trial. The validity test is done using the Microsoft Excel application. . The instrument can be said to be valid if tcount > ttable. After the validity test, the reliability test was carried out to assess the level of confidence of measuring instrument in producing consistent and stable measurement results. Reliability is categorized as in Table 4.

Table 4. Reliability criteria

Reliability Coefficient (r)	Criteria
$0.00 \leq r \leq 0.20$	Very Low
$0.20 \leq r \leq 0.40$	Low
$0.40 \leq r \leq 0.60$	Medium
$0.60 \leq r \leq 0.80$	High
$0.80 \leq r \leq 1.00$	Very High

Data Analysis

After conducting the validity and reliability tests, which were found to be valid and reliable, the research proceeded with prerequisite tests. The prerequisite tests included descriptive analysis, normality test, homogeneity test, and t-test, utilizing SPSS 26 software. The normality test was conducted to confirm that the research data follows a normal distribution. Meeting this assumption is crucial for applying various statistical analysis techniques. This test is a critical step in data analysis as it helps ensure that the data has a normal distribution. A normal distribution of data is necessary to meet the assumptions of various statistical methods. There are two criteria to assess normality: data is considered normally distributed when the achieved significance value is greater than the formulated significance level of 0.05. However, if the significance value is less than 0.05, it can be concluded that the data does not follow a normal distribution (Sundayana, 2018).

The homogeneity test is used to verify that the two sample groups, namely the experimental and control groups, come from a homogeneous population. The homogeneity of variance is tested using Levene's Test through the SPSS 26 statistical software. Data is considered to have homogeneous variance if the significance value exceeds 0.05. Through the t-test, significant differences observed are statistically significant, allowing for the conclusion that there is a difference between the two groups. The subsequent statistical analysis is the gain test to determine the improvement in problem-solving skills. The categories for N-gain levels are presented in Table 5.

Table 5. Normalized N-gain criteria

Average	Criteria
$g > 0.7$	High
$0.3 \leq g \leq 0.7$	Medium
$0 < g < 0.3$	Low
$g \leq 0$	Failed

▪ RESULT AND DISSCUSSION

This study involved three data collection periods focusing on the topics of vibrations and waves, where the experimental class received treatment according to the guided inquiry integrated STEM syntax outlined in Table 1. Based on this, it is evident that the first syntax, which involves presenting a problem integrated with the science aspect, guided the students to identify the issue presented through a video and narrative provided in the student worksheets (LKPD). In the second syntax, which involves forming a hypothesis integrated with the science aspect, students were guided to create hypotheses based on their own thoughts. The science aspect in both of these syntaxes serves as a guide for students to explore the initial concepts that have already formed in their minds. In the third syntax, designing an experiment integrated with the technology aspect, students were given the opportunity to design a product and steps to solve a problem. The technology aspect in this syntax served as a guide for students in planning and creating something. In the fourth syntax, conducting experiments to collect data integrated with the engineering aspect, students performed experiments using the products they had created to gather data, which was then recorded in the LKPD. The engineering aspect in this syntax guided students in applying natural science and mathematics by analyzing, designing, and investigating scientifically. In the fifth syntax, analyzing data and testing hypotheses integrated with the mathematics aspect, students were guided to calculate and analyze the data they had obtained. In the final syntax, drawing conclusions integrated with the mathematics aspect, students were guided to form conclusions. The mathematics aspect in both of these syntaxes served as a guide for students to use mathematical concepts through analysis, design, and scientific investigation.

The activities in the following meetings, namely the second and third meetings in this study, had a similar format, but with variations in the material studied through the LKPD. In the first activity, the topic studied was vibrations, while in the second and third activities, the topics studied were transverse waves and longitudinal waves. Furthermore, in the final meeting, students were given a set of 10 essay questions to assess their ability to solve problems. Each question was designed to evaluate the students' problem-solving abilities at each stage of the process.

Validity and Reliability Testing

The questions to be used in the research must undergo a validation process to ensure that they are appropriate and have the correct level of difficulty. Validation is carried out by a validator lecturer with expertise in the relevant field, and the results of the validation are declared valid. Before being used in the study, both the pretest and posttest questions are tested for validity and reliability. A pilot test is conducted on 30 students to ensure the quality of the questions. The data obtained from the field test implementation is analyzed using Microsoft Excel software. To measure the students' initial and final knowledge, this study employs 10 essay questions for both the pretest and posttest. The results of the validity test for the essay questions can be seen in Table 6.

Table 6. Validity test result

No	r_{count}	r_{table}	Description
1	0.635	0.361	Valid
2	0.542	0.361	Valid
3	0.777	0.361	Valid
4	0.410	0.361	Valid
5	0.773	0.361	Valid
6	0.504	0.361	Valid
7	0.503	0.361	Valid
8	0.644	0.361	Valid
9	0.417	0.361	Valid
10	0.461	0.361	Valid

Furthermore, all valid questions were tested for reliability using SPSS, the reliability coefficient result was 0.756, thus it can be seen that the reliability results passed the minimum reliability threshold of 0.6. This can be interpreted that this test instrument is considered reliable and belongs to the high category.

Descriptive Analysis

Based on descriptive analysis of data assisted by SPSS ver 26 software, it is presented in Table 7.

Table 7. Descriptive analysis of problem solving skills

	Descriptive Statistics				
	N	**Minimum**	**Maximum**	**Mean**	**Std.Deviation**
Experiment Pretest	30	22	49	37.30	5.855
Experiment Posttest	30	30	87	76.90	5.786
Control Pretest	30	27	43	36.00	4.119
Control Posttest	30	50	79	59.40	6.441

Based on the data in Table 7, the pretest results in the experimental class before the intervention show a mean score of 37.30, indicating that students' problem-solving skills, as per Table 4, are categorized as very low. After the implementation of the guided inquiry model integrated with the STEM approach in the experimental class, the posttest score showed an improvement with a mean score of 76.90. These data indicate that the students have good problem-solving skills. Meanwhile, the pretest results for the control class had a mean score of 36.00, indicating that students' problem-solving skills were low. After being given the treatment with conventional teaching methods, the posttest score showed an improvement with an average score of 59.40, indicating that students' problem-solving skills were at a moderate level. This study demonstrates a significant improvement in students' problem-solving skills. This suggests that the chosen teaching approach is crucial in supporting academic progress and enhancing students' problem-solving abilities.

Normality Test

Before conducting further analysis, the initial and final score data of both groups were tested for normality in order to verify the normality of the data. The results of the normality test are listed in Table 8.

Table 8. Normality test

	Shapiro-Wilk		
	Statistic	**df**	**Sig**
Experiment Pretest	0.968	30	0.493
Experiment Posttest	0.950	30	0.169
Control Pretest	0.980	30	0.829
Control Posttest	0.936	30	0.072

The experimental group given the STEM-integrated Guided inquiry model learning obtained a significance result of 0.493 in the pretest and a posttest significance result of 0.169. The results of the analysis showed that students in the control group given conventional learning obtained a significant value of 0.829 pretest and 0.072 posttest, which was lower than the experimental class. From the analysis conducted, it can be concluded that the data from both classes have met the normality requirements, so they can proceed to the next statistical analysis.

Homogenity Test

Before proceeding to a more in-depth analysis, a homogeneity test was conducted to ensure that the pretest and post-test data from the experimental and control groups had uniformity in data distribution. The results of the homogeneity test and the pretest and post-test data for both classes are listed in Table 9.

Table 9. Homogenity test result

Homogenity Test of Variance					
		Levene Statistic	**df 1**	**df 2**	**Sig.**
Experiment and Control *Pretest*	Based on mean	1.772	1	58	0.188
Experiment and Control *Posttest*	Based on mean	0.239	1	58	0.627

The data listed in Table 9, proves that the pretest in the experimental and control groups reached 0.188 and the posttest homogeneity test in the experimental and control groups was 0.627. Based on the calculations carried out, the conclusion that can be drawn is that both data sets have homogeneous characteristics. Based on the results of the analysis of the two data has a value of Sig. > 0.05 so it can be stated that the data obtained has a homogeneous variance.

Independent Sample t- Test

The next step is to apply the parametric Independent Sample t- Test, because the data obtained has been declared normally distributed and has a homogeneous variance. The data used for this test is pretest and posttest data from experimental and control classes. This test aims to determine whether there are differences in students' problem solving skills between the experimental class and the control class. The results of the Independent Sample t-Test can be seen in Table 10.

Table 10. Independent sample T test

Levene's Test for Equality of Variances					
	F	**Sig.**	**t**	**df**	**Sig. (2-tailed)**
Equal variances assumed	0.239	0.627	11.071	58	.000
Equal variances not assumed			11.071	57.344	.000

The data results seen in Table 10 are Sig. (2-tailed) of 0.000 <0.05. The learning outcomes of students who follow the guided inquiry STEM model on vibration and wave material are better when compared to conventional model learning. This study concludes that STEM-integrated guided inquiry is successful in improving students' cognitive abilities, especially in terms of problem solving related to vibration and wave concepts. The results of this research are consistent with previous studies such as those researched by Lewa et al. (2018) and Mustika et al. (2021). Both studies state that learning with the STEM-integrated guided inquiry model has a positive effect on the development of students' problem solving skills. Research conducted by Ristanti et al. (2023) also said that learning with the guided inquiry model improved students' problem solving skills. This study shows that student- centered learning approaches, such as guided inquiry and STEM, successfully improve students' ability to interpret concepts and solve problems.

This study confirmed the results of previous research conducted by Putri & Juandi (2023) that the STEM approach succeeded in improving students' problem solving skills.

N- Gain Test

The N-Gain test was obtained from the dissimilarity between pretest and posttest scores in both classes. This study uses statistical tests to determine whether the learning model used is truly effective. The results of the N-gain test can be seen in

Table 11. N-Gain test result

Class	Description	Explanation
Experiment	0.63	Medium
Control	0.37	Medium

Based on the data recorded in Table 11, it can be seen that the N-Gain value in the experimental group reached 0.63, indicating that the increase in students' problem solving skills was classified as moderate. In contrast, the N-Gain value in the control group was only 0.37, indicating a lower increase in the medium criteria. Both groups are in the same category, namely the moderate category. This is because students from the experimental and control groups have similar characteristics. In addition, the experimental group has comparable initial potential in learning motivation and initial ability of students. This is in line with research conducted by Hattie & Gregory C.R (2013) and Shadish et al. (2002) which explains that the factor that causes the n-gain of the two groups to be balanced is that the learners in the experimental group have the same initial potential. The results of this analysis revealed that there was a more significant increase in problem solving skills among learners in the experimental group who applied the STEM-integrated guided inquiry model compared to the conventional learning, namely the control class. The results of this analysis revealed that there was a more significant increase in problem solving skills in students in the experimental group who applied learning with the STEM-integrated guided inquiry model compared to conventional learning, namely the control class.

N- Gain Indicators of Student’s Problem Solving Skills

Based on the results of the calculation in the experimental group, students' problem solving skills experienced a more significant increase. This significant increase can be seen through the increase in each indicator of problem solving skills. The results of the increase are in Figure 1.

The graph above shows the first aspect, which is understanding the problem, where the experimental group achieved an N-gain of 0.42 and the control group had a score of 0.38. Both fall within the moderate category, but the experimental group demonstrated a significant improvement. This analysis concludes that the treatment in the experimental group significantly enhanced students' ability to understand the problem. This is supported by the guided inquiry learning model, specifically the syntax of presenting problems and forming hypotheses integrated with the science aspect. In this syntax, students are guided to identify the problem and formulate hypotheses for solving it in the LKPD.

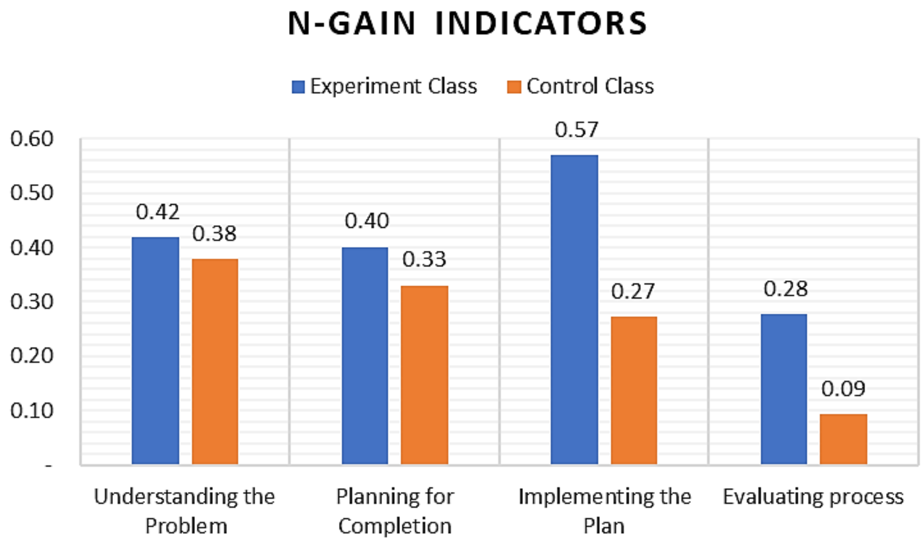

Figure 1. Graphics of N-Gain indicators

The second aspect, which is formulating problem-solving solutions, shows a moderate improvement in the experimental class with an N-gain of 0.40, while the control group had a score of 0.33. Both groups fall within the moderate criteria, but the experimental class exhibited a higher rate of improvement. The conclusion drawn from this data is that students in the experimental group demonstrated more significant improvement in their ability to formulate solutions compared to students in the control group. This result is supported by the guided inquiry learning syntax, particularly in designing experiments, which is integrated with the technology aspect. In this syntax, students engage in research, gather data/references/resources to solve the given problem, and describe the products they will create and use.

The third aspect, executing the problem-solving process, shows a moderate improvement in the experimental class with an N-gain of 0.57, while the control group shows a lower improvement with a score of 0.27. The comparison between the two groups reveals that the experimental group made more significant progress in terms of problem-solving ability. This is supported by the guided inquiry learning syntax of conducting experiments, integrated with the engineering aspect. In this syntax, students assemble the products they have designed and conduct experiments using the tools they have made. Additionally, the syntax of gathering and analyzing data, integrated with the mathematics aspect, supports this process. Students enter the data they have collected into a table on the LKPD and perform calculations on the data.

The fourth aspect, evaluating the solution, shows that the experimental group achieved an N-gain of 0.28, which falls into the low category, while the control group achieved a score of 0.09, falling into the very low category. The comparison between the two groups shows that the experimental group improved more significantly in their evaluation skills. This improvement is supported by the guided inquiry learning syntax, particularly in drawing conclusions, integrated with the mathematics aspect. In this syntax, students summarize the data obtained from the experiments.

The guided inquiry model integrated with STEM has proven effective in improving students' problem-solving skills. This model is capable of optimizing students' problem-solving skills, which in turn strengthens holistic learning. The learning process becomes more meaningful, relevant, and focused on the development of students as complete individuals. guided inquiry with STEM to optimize students' problem-solving skills. This aligns with research conducted by (Maharani et al., 2020), (Lewa et al., 2018), (Mustika et al., 2021) and ,which explains that combining inquiry with a STEM approach can produce significant positive impacts. This factor is due to students being actively engaged and challenged to solve problems with the products they design. The author recognizes that the guided inquiry model still has shortcomings, as demonstrated in this study, which is why the author integrated.

Although the guided inquiry model integrated with STEM offers many advantages, it also has some potential drawbacks that need to be considered in its implementation. One of the main challenges is the longer time required, as the exploration, investigation, and product creation processes involved in the STEM approach are complex. Additionally, this model requires adequate facilities and resources, such as laboratories, technology devices, and experimental materials, which could be a constraint in schools with limited budgets. The success of this learning model also heavily depends on the teachers' abilities, so intensive training is necessary to ensure that teachers can effectively guide students. Furthermore, this approach may not be suitable for all types of materials, especially those that are conceptual or theoretical. Another challenge is classroom management, particularly in heterogeneous classes where students with low abilities or motivation may struggle to keep up with the learning process. Assessment also becomes more complex as it must encompass both the process and the outcome of learning. The high cognitive load on students and the lack of support from the learning environment can serve as additional obstacles. Therefore, appropriate strategies, such as teacher training, effective time management, and the provision of adequate resources, are needed to address these limitations and optimize the benefits of guided inquiry learning integrated with STEM.

▪ CONCLUSION

This study states that the guided inquiry learning model integrated with STEM has proven to be more effective in enhancing problem-solving skills in the topic of vibrations and waves. The learning outcomes of students in the experimental group showed a significant increase, as evidenced by a mean posttest score increase of 17.5 compared to the control group. This is further supported by the independent t-test, which yielded a Sig.(2-tailed) value of $0.000 < 0.05$, thus concluding that there is a significant difference in the mean learning outcomes between the guided inquiry STEM-integrated learning model and the conventional learning model. This effect is also observed based on the N-Gain evaluation, where the experimental group achieved an N-Gain of 0.63, indicating a moderate improvement in students' problem-solving skills. In contrast, the N-Gain value in the control group was only 0.37, indicating a lower improvement, still within the moderate category.

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