e-ISSN: 2355-620X
DOI: 10.12928/jrkpf.v13i1.1564

Transformation of sound wave learning with the MURDER model: Its influence on students' problem-solving skills

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Abstract

This study aims to analyze the effect of implementing the MURDER (Mood, Understand, Recall, Digest, Expand, Review) learning model on students' problem-solving skills in the concept of sound waves through direct practice, with a focus on problem identification, hypothesis formulation, and solution evaluation. A quasi-experimental approach was used with a matched-only posttest-only control group design. This design was chosen because the existing classroom conditions did not allow for complete randomization, yet still ensured equal characteristics between groups. The research population included 155 grade XI science students at one of the Madrasah Aliyah (Islamic high schools) in Tasikmalaya Regency, with two classes (a total of 64 students) selected through purposive sampling. Data were collected using post-test essay questions that assessed problem-solving skill indicators: problem identification, hypothesis formulation, solution implementation, and result evaluation. The hypothesis test results showed that t count (15.13) > t table (1.67), indicating a significant difference between the experimental and control groups. Substantively, students taught using the MURDER model demonstrated higher problem-solving skills compared to students taught conventionally. Therefore, the MURDER model can be recommended as an effective instructional strategy to enhance students' problem-solving skills in physics learning.

Keywords: MURDER, Problem-solving skills, Sound waves

Article submitted 2025-06-23. Revision uploaded 2025-11-15.
Accepted for publication 2026-01-28.
Available online on 2026-04-30.
https://doi.org/10.12928/jrkpf.v13i1.1564

I. Introduction

Education is a deliberate and structured process that creates a learning environment that encourages students to develop their spiritual potential, character, self-discipline, intellectual abilities, and moral values necessary for personal, social, national, and global life [1]. Through education, individuals can develop and optimize their abilities and talents, contributing meaningfully to society [2]. In the national context, Indonesia is striving to improve the quality of education through the implementation of the Merdeka Curriculum, which gives teachers and students the freedom to tailor learning to students' needs, interests, and characteristics [3]. This curriculum opens up great opportunities to strengthen the quality of science learning, especially physics, by emphasizing active, contextual, and problem-solving-oriented learning. Through this approach, students are expected not only to understand physics concepts theoretically but also to apply them in real situations, in line with the objectives of this study, which focus on improving students' problem-solving skills in sound wave concepts through the application of the MURDER learning model.

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The Independent Curriculum aims to provide space for freedom of thought and opinion in the learning process, with the hope that education can guide individuals towards freedom, both physical and mental [4]. The Independent Curriculum emphasizes the development of students' character and skills by reducing the burden of material and memorization tasks in the learning process [5]. According to the Ministry of Education, Culture, Research, and Technology, physics education aims to foster students' scientific reasoning, critical thinking, and problem-solving skills. In addition to being part of the Independent Curriculum, problem-solving skills are important competencies for 21st-century learning.

21st-century learning emphasizes character development, creativity, critical thinking, collaboration, problem-solving, and communication and social skills [6]. In the era of the Fourth Industrial Revolution, 21st-century learning requires mastery of key skills, such as critical thinking, creativity, collaboration, communication, and especially problem-solving, as competencies that determine the quality of human resources in education and the world of work [7].

Researchers conducted a preliminary study at one of the Madrasah Aliyah (Islamic high schools) in Tasikmalaya Regency that has implemented the Merdeka Curriculum. However, the learning process is still dominated by lecture methods, so that learning interactions tend to be one-way and student active participation is still low. Based on interviews with 11th-grade physics teachers, students have difficulty solving problems during the learning process. An initial evaluation of problem-solving skills showed that students' average test score was only 33.78%, which is very low. In addition, for the sound waves topic, the average daily test score was only 55.2 out of a minimum passing grade of 77, indicating a low level of student understanding of the material. These findings are in line with previous research, which found that 57.7% of respondents reported difficulty understanding sound waves [8]. These findings indicate a gap between the implementation of the Merdeka Curriculum and the learning conditions in the field, thus reinforcing the urgency of efforts to improve students' problem-solving skills.

Problem-solving skills in physics are an important ability that students must have, because they not only help them solve physics problems at school, but are also useful in dealing with various problems in everyday life [9]. Physics requires students to analyze natural phenomena, relate them to scientific concepts, and find appropriate solutions, making this competency one of the main objectives of physics education [10]. However, in reality, students' problem-solving skills are still relatively low, requiring efforts to develop these abilities [11] According to the indicators proposed by Docktor & Heller, problem-solving skills in physics cover several important aspects, namely understanding the problem at hand, representing the problem using physics principles, designing solutions by applying physics concepts and mathematical procedures, solving problems systematically, and evaluating the solutions obtained [12]. These indicators are important references for research to identify and analyze students' difficulties in solving physics problems.

A limited understanding of physics concepts directly impacts students' low problem-solving skills. One strategy to overcome this problem is to apply a learning model that can increase students' active engagement and problem-solving skills [13]. The Mood, Understand, Recall, Digest, Expand, Review (MURDER) learning model was chosen because it creates a more interactive, enjoyable, and engaging learning environment, encouraging students to participate actively, think critically, and develop problem-solving skills that were previously lacking when learning was dominated by lecture methods [14].

The MURDER model is a collaborative, constructivist learning approach that is effective for improving students' problem-solving skills. This model helps build a positive learning environment, encourages active engagement, and deepens students' understanding through concept reinforcement, exploration, material expansion, and evaluation [15]. In addition, student collaboration through discussion and teamwork strengthens analytical and evaluative skills, which are important aspects of the physics problem-solving process [16]. Several studies have demonstrated that the MURDER model improves learning outcomes and mathematical abilities. However, these studies tend to focus on general achievement rather than higher-order thinking skills such as problem-solving, particularly in physics contexts.

Previous research on the MURDER model has mostly focused on improving general learning outcomes or mathematical skills. However, no research has specifically highlighted the application of this model to improve problem-solving skills in physics sound-wave material. This study aims to fill this gap by evaluating the effectiveness of the MURDER model in improving students' problem-solving skills in sound-wave topics, thereby providing more effective and relevant learning strategies [17].

Based on these findings, the researcher intends to study the outcomes of implementing the MURDER model in the learning experience, carried out through direct practice and supported by educational games on sound-wave material, to improve students' problem-solving skills. What sets this study apart from previous research is the dependent variables analyzed. If in previous studies the MURDER model was used as an independent variable with learning outcomes as the dependent variable, both in general and in the field of mathematics, this study specifically highlights problem-solving skills as the primary emphasis [17]. In addition, another study applies the MURDER model, focusing on students' mathematical understanding skills [18]. In contrast to previous studies, this research focuses on students' problem-solving skills, particularly in the context of sound-wave topics in physics education. This provides a new perspective in evaluating the effectiveness of the MURDER model in fostering higher-order thinking skills. Additionally, this study may serve as a useful reference for teachers in applying more structured and engaging learning approaches.

II. Methods

This study was conducted at a Madrasah Aliyah (Islamic high school) in Tasikmalaya Regency, using a quantitative, quasi-experimental design. A quasi-experimental design was chosen because the research conditions in the school environment did not allow for full randomization of participants, as required in a pure experiment. Therefore, this design was considered more realistic for the context of formal education. This study used a Matching-Only Posttest-Only Control Group design, in which the experimental and control groups were matched on initial ability. This matching approach was chosen to ensure the equivalence of characteristics between the two groups even without a randomization process, so that the results obtained could still validly reflect the effect of the treatment.

The experimental group received treatment through the MURDER Model, while the control group received instruction through the Direct Instruction Model as a conventional method. The treatment for each group was delivered over 4 sessions, each lasting 3×45 minutes, ensuring participants received equal learning time. To maintain the quality and consistency of learning, both groups were taught by the same teacher using identical teaching materials and learning time, so that differences in results were more likely to be caused by differences in the learning models used. After all treatment sessions were completed, both groups took a final exam to evaluate their problem-solving abilities. The results of both groups were then analyzed and compared to explore the effect of applying the MURDER Model on students' problem-solving abilities. The structure of this research design is presented in Table 1, which follows the Matching-Only Posttest-Only Control Group Design format [19].

Table 1. Matching-Only Posttest-Only Control Group Design

E	M	X	O_1
K	M		O2

The symbol E refers to the experimental class, while K refers to the control class. The symbol M indicates the matching of research subjects to ensure comparability between groups. The treatment applied in this study is denoted by X, which represents the implementation of the MURDER learning model. Furthermore, Q_1 represents the post-test administered to the experimental group, and Q_2 represents the post-test administered to the control group.

The population in this study comprised all XI-grade students majoring in Science and Technology (phase F) at a Madrasah Aliyah in Tasikmalaya Regency, comprising five classes with a total of 155 students. The selection of 11th grade as the research population was based on the consideration that students at this level already had sufficient knowledge, making it relevant to examine the application of the MURDER Model in the development of problem-solving skills. The focus on phase F was chosen because it is part of the implementation of the Merdeka Curriculum, which emphasizes competency-based learning and the strengthening of the Pancasila student profile. Information regarding the data on the phase F grade XI population was obtained from official school documents in the form of academic lists and student administrative data, which are presented in Table 2.

This study used purposive sampling, which is a sampling technique based on predetermined criteria. Selection was based on matching participant characteristics to obtain a representative sample of the population. In this study, each Physics, Science, and Technology class served as a population unit. The main criterion in determining the sample was the students' test scores, which were used as the basis for calculating the standard deviation and assessing the students' initial ability levels. This test score-based selection was carried out to ensure that the experimental and control classes had relatively equivalent initial abilities, so that differences in learning outcomes could be more accurately attributed to the application of different learning models. In addition, the number of students in each class was also taken into consideration to ensure a balanced distribution of participants between the two groups. A homogeneity-of-variance test using standard deviation values was also conducted to assess the uniformity of characteristics across classes. Based on the results of these calculations, two classes were selected as samples, namely Grade XI Science and Technology 2 as the experimental group and Grade XI Science and Technology 5 as the control group, each consisting of 32 students.

Table 2. Grade XI Physics Student Population (Phase F)

Class	Number of Students
XI Science and Technology 1	29
XI Science and Technology 2	32
XI Science and Technology 3	32
XI Science and Technology 4	30
XI Science and Technology 5	32
Total	155

In this study, data were collected through problem-solving skill assessments in the form of essay questions. Essay questions were chosen to assess the depth of students' conceptual understanding and analytical thinking skills comprehensively [20]. The test instrument consisted of six essay questions, each designed to measure five main indicators of problem-solving skills, namely: (1) useful description, (2) physics approach, (3) specific application of physics, (4) mathematical procedures, and (5) logical progression. This instrument was administered as a post-test to generate quantitative data on students' problem-solving skills after applying the MURDER Model to the experimental group. In addition, supporting data were obtained through non-test methods using observation sheets completed by three independent observers. These observation sheets were used to assess the suitability of the MURDER Model's application with the lesson plan during physics teaching activities in the experimental class. To ensure inter-rater reliability, the observation results from the three observers were compared and analyzed using the inter-rater agreement coefficient. This approach helped minimize observer subjectivity and enhance the validity of the observed data.

The tools used in this study included problem-solving skill tests and observation sheets, which served as data-collection instruments to monitor the implementation of the learning model. The data obtained from the problem-solving skill tests were analyzed using descriptive and inferential analysis. Descriptively, percentage calculations were used to describe student achievement on each problem-solving skill indicator. The percentage formula followed the standards set forth in the methodological literature [21].

$$P = \frac{f}{N} \times 100\% \tag{1}$$

P is the percentage, f is the frequency of students who meet the criteria, and N represents the maximum score (ideal).

The scores are subsequently classified by indicator and presented in Table 3 as follows.

Table 3. Categorization of Problem-Solving Skills

Percentage (%)	Category
0 – 39.9	Very less
40 – 54.99	Not enough
55.00 – 69.99	Enough
70.00 – 84.99	Good
85.00 – 100.00	Very good

Furthermore, to strengthen the inferential validity of this study, prerequisite tests were conducted, such as normality and homogeneity of variance tests (e.g., Levene's test) and independent t-tests to examine whether there were significant differences between the experimental and control groups. The observation data were analyzed by calculating the average score from the observation sheets filled out by three observers, then converted to a percentage to assess the level of consistency in the implementation of the learning model in the experimental class

The next data analysis technique involved examining the implementation of the MURDER model through an observation sheet using the Guttman scale. The Guttman scale was chosen because it provides a clear and objective assessment of the implementation of each component of the learning model, with only two response categories, namely "yes" (1) and "no" (0) [22]. This scale was chosen based on the need to identify precisely whether each step in the MURDER model had been implemented according to procedure or not, rather than to measure the level of intensity or observer perception as in the Likert scale [23]. The results of the observations from the three observers were then processed in the form of a percentage of implementation, which was calculated using the following formula:

$$P = \frac{\text{The Number of Scores Obtained}}{\text{Maximum Score}} \times 100\% \quad (2)$$

This percentage value illustrates the level of consistency and completeness of the MURDER model implementation during the learning process. Thus, the use of the Guttman scale in this study is not only supplementary but also serves to ensure the suitability of the learning model's application to its theoretical design, in a quantitative and measurable manner.

Instrument development analysis was conducted to assess the feasibility and suitability of the instruments used in this study. Before the test instruments were given to students, content validity testing was conducted using Aiken's V formula, which assesses the extent to which each item reflects the problem-solving ability construct being measured. The validation process was carried out by three experts, consisting of physics education lecturers and physics teachers, to ensure the representativeness of the material and the suitability of the indicators.

In the initial stage, the test instrument consisted of eight essay questions; after validation, two were eliminated as irrelevant to the problem-solving ability indicators. Thus, six final questions were used in this study. The results of Aiken's V coefficient calculation showed that all retained items had values above the minimum feasibility threshold, indicating they were valid in terms of content and feasible for use in data collection [24].

$$V = \frac{\sum s}{\left[n\left(c-1\right)\right]} \quad (3)$$

s is $r - l_0$, where l_0 is the minimum score used for validity assessment (in this case, = 1), c is the maximum score allowed in the validity evaluation, r is the score assigned by the expert evaluator, and n is the total number of expert raters.

The coefficient value V is interpreted in Table 4 as follows.

Table 4. Interpretation of Validity Coefficient

Percentage (%)	Category
$0.6 \leq V \leq 1$	Valid
$V < 0.6$	Invalid

After conducting content validity testing, the next step was to test the instrument to ensure that it was empirically valid and appropriate for use. This test was conducted on 32 students with characteristics similar to those of the main research population. The test subjects were selected from outside the research sample in order to avoid bias in the results due to exposure to the same instrument during the main study.

The validity of the items was analyzed using Pearson's product-moment correlation based on raw scores. Based on the analysis results, six post-test items were declared valid: 1, 3, 5, 8, 10, and 11, which covered the subtopic of sound waves. These six items were selected because they had the highest validity coefficients, so they were considered the most representative in measuring students' problem-solving skills.

Furthermore, a reliability test was conducted using Cronbach's alpha, yielding a coefficient of 0.764, which is considered high reliability. Before conducting the hypothesis test, a prerequisite analysis test was also conducted, including a normality test using the chi-square method and a homogeneity test using the Fisher test, to ensure that the data met the necessary statistical assumptions.

III. Results and discussion

In this study, the experimental group was taught using the MURDER learning model, while the control group followed the Direct Instruction approach on the topic of sound waves. The treatment was given for 4 weeks, with 1 session per week, each lasting 3×45 minutes, so that the teaching intensity in both groups was relatively the same. Before the treatment, students' daily test scores were observed to assess their initial problem-solving skills. The pretest results showed that both groups had relatively comparable initial abilities, so the initial conditions of the experimental and control groups were considered homogeneous.

At the end of the teaching period, both groups completed a final test (post-test) consisting of six validated essay questions to evaluate students' problem-solving abilities. The post-test results for both classes are presented in Table 5, which was further analyzed to evaluate the effect of applying the MURDER model compared to conventional methods.

Table 5. Post-test Statistical Data of Problem-Solving Skills

Percentage (%)	Class	
	Experiment	Control
Number of Students	32	32
Ideal Score	150	150
Highest Score	144	111
Lowest Score	117	78
Average	131.72	95.16
Variance	90.79	95.94
Standard Deviation	9.53	9.80

According to Table 5, the experimental class had a higher average score than the control class. This difference suggests that applying the MURDER model has the potential to improve students' problem-solving skills compared to the Direct Instruction method. In addition, the experimental class had a smaller standard deviation, indicating that student scores were more centered on the mean and resulting in more consistent learning outcomes among participants. This can be interpreted as meaning that the application of the MURDER model not only improved individual achievement but also increased the uniformity of understanding in the class, which may have been due to the step-by-step approach and systematic learning structure. Visualization of the score distribution using histograms and polygons (Figure 1) reinforces these findings by showing that most students in the experimental class clustered at high scores, while the control class showed a more spread-out distribution. Thus, these data support the effectiveness of the MURDER model in improving and stabilizing students' problem-solving skills in sound waves.

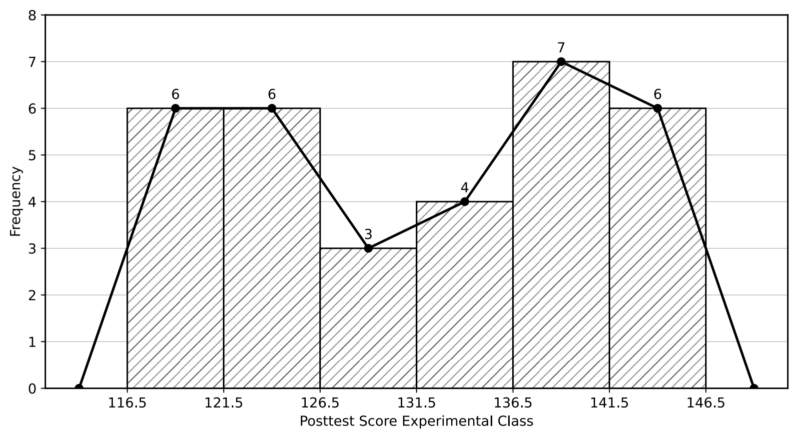

Figure 1. Post-test Problem-Solving Skills Distribution (Experimental Class)

Figure 1 shows the distribution of post-test scores for problem-solving skills in the experimental class. This distribution is more concentrated at high scores, with most students scoring between 136.5 and 146.5, indicating that the majority of participants achieved good results evenly. The relatively stable frequency in the high score range and little dispersion indicate consistency in learning outcomes in the experimental class. In contrast, the distribution of scores in the control class tended to be more spread out, with some students scoring low, indicating greater variation in understanding among participants. These findings imply that the MURDER model not only improves average achievement but also strengthens the consistency of student understanding, making it more effective in facilitating structured and equitable learning in the classroom.

Based on the data obtained, the average post-test score for the experimental class was 131.72, with a median of 132 and a mode of 144. The difference between the mean, median, and mode shows that the score distribution tends to be skewed to the left (negative), meaning that most students were in the medium-high score range, but there were some students with lower scores. A more in-depth analysis of the problem-solving skill indicators shows that the indicators of problem identification and solution planning experienced the most significant improvement after the implementation of the MURDER model. In contrast, the indicators of result evaluation or reflection on solutions still showed relatively lower scores. These findings provide practical information for teachers: although the MURDER model is effective in improving students' overall abilities, some aspects of problem-solving, especially those that are reflective in nature, require additional attention through more structured guidance or practice. The distribution of post-test scores for the control class is shown in Figure 2 for comparison, with a wider spread of scores and fewer high scores than in the experimental class [25].

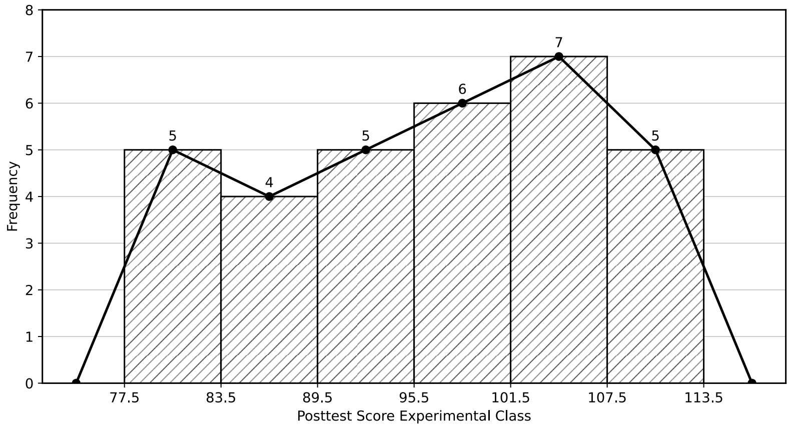

Figure 2. Post-test Problem-Solving Skills Distribution (Control Class)

Figure 2 shows the distribution of post-test scores for problem-solving skills in the control class, with an average of 95.16, a median of 96, and a mode of 102, indicating that the distribution tends to be skewed to the left (negative). Compared to the experimental class, the control class scores are lower and more scattered, indicating that students' problem-solving abilities are less evenly distributed.

Post-test analysis based on the average percentage of each indicator (5 indicators through 6 essay questions) shows a clear difference between the experimental and control classes. The t-test results show that the t-count is significantly greater than the t-table, so it can be concluded that the MURDER model significantly improves students' problem-solving skills compared to the Direct Instruction method.

In addition, the results of observing the implementation of the MURDER model show concrete evidence: the majority of the learning syntax was carried out according to plan, with an implementation percentage for each step between 85–95%, indicating that the model was applied consistently and effectively. These findings reinforce the conclusion that the improvement in problem-solving skills was not only due to the method used but also due to the proper implementation of MURDER during learning.

Based on Table 6, the problem-solving abilities of students in the experimental class are classified as very good, with average scores for each indicator surpassing those of the control class, which fall into the good category. All indicators in the experimental group show higher percentages, highlighting the effectiveness of the implemented learning strategy, such as the problem-based learning model, in improving students' conceptual understanding and problem-solving capabilities.

Information regarding the implementation of the MURDER model was gathered using observation sheets completed by three observers. Their evaluations aimed to assess how effectively the MURDER model was applied in the experimental class. The analysis results indicated that each phase of the MURDER model was executed successfully, from the initial activities to the concluding ones. Before testing the research hypothesis, prerequisite tests were conducted to evaluate the normality and homogeneity of the collected data. The results of the normality test are presented in Table 7.

Table 6. Average post-test score

Indicator	Experimental Class		Control Class	
	Percentage (%)	Category	Percentage (%)	Category
Useful Description	91.15	Very good	75.56	Good
Physics Approach	83.54	Good	80.57	Good
Specific Application of Physics	91.56	Very good	72.43	Good
Mathematical Procedures	92.71	Very good	72.11	Good
Logical Progression	80.10	Good	74.85	Good
Average	87.81	Very good	75.10	Good

Table 7. Normality Test Results

Data	χ^2_{count}	χ^2_{table}	Decision
Post-test scores of the experimental class	10.46	12.84	Normally Distributed Data
Post-test scores of the control class	6.98	12.84	Normally Distributed Data

The findings from the homogeneity test analysis are presented in Table 8.

Table 8. Homogeneity Test Results

Data	α	F_{count}	F_{table}	Decision	Conclusion
Post-test scores of Problem Solving Skills experimental and control classes	0.05	1.06	1.82	H_0 accepted	Both variances are the same or homogeneous.

A summary of the data processing and the results of the hypothesis test analysis (t-test) is provided in Table 9.

Table 9. t-Test Results

Data	Post-test		α	t_{count}	t_{table}	Decision
	Experimental Class	Control Class				
Number of Students	32	32	0.05	15.13	1.67	H_0 rejecter H_a accepted
Average score	131.72	95.16				
Standard Deviation	9.53	9.80				
Variance	90.79	95.94				

Implementing the MURDER model influences students' active participation and enthusiasm throughout the learning process. This aligns with expert opinions stating that the MURDER model promotes greater student engagement and fosters high learning motivation [26]. This research demonstrated that applying the MURDER learning model positively contributes to enhancing students' problem-solving abilities in sound wave topics. This model is considered effective because it emphasizes the active involvement of students through structured learning steps, starting from creating a pleasant learning atmosphere (Mood) to the evaluation and reflection stage (Review).

The Useful Description indicator assesses students' ability to understand and explain material through summarizing important information. In the experimental class, this indicator was trained through the Mood, Understand, and Recall syntax, for example, by observing sound wave phenomena using educational games, discussing the concepts of frequency and amplitude, and reactivating basic understanding through questions and real experiences. As a result, students in the experimental class were better able to extract key information and answer questions accurately compared to the control class, which only followed conventional learning without interactive activities and layered understanding activation [27].

The Physics Approach Indicator assesses students' ability to determine relevant physics concepts and principles to solve problems, through the Mood, Understand, and Recall syntax. In the experiment class, students are encouraged to think logically and develop hypotheses through educational games such as “singing glasses” and “hand swings” to connect phenomena with the concepts of resonance and interference. The Understand syntax emphasizes deepening concepts and testing hypotheses through discussion and reference searches, while Recall links theory to real phenomena through reflection and practical explanations. Despite the implementation of MURDER, some students still experienced misunderstandings in determining derivative concepts. This was likely due to limited learning time, varying levels of student readiness, and the complexity of physics concepts that require gradual understanding. Thus, despite improvements, conceptual understanding was not yet fully uniform across all students [28].

The Specific Application of Physics indicator measures students' ability to select and apply physics equations appropriately according to the problem, related to the Digest, Expand, and Review syntax. In the Digest syntax, students conduct resonance and quenching practices, such as a resonance tube with a tuning fork and two tuning forks with different frequencies. This syntax is the most dominant because students directly apply concepts and equations in real contexts. The Expand syntax focuses on the application of practical results through discussions and presentations, in order to systematically connect theories, data, and equations. The Review syntax directs students to reflect on the application of concepts, such as the relationship between wavelength and sound speed, and their variations in different conditions. This strengthens understanding and analytical skills in applying concepts scientifically and contextually. Specific Application of Physics is the activity of applying concepts and principles according to the problem. Students can link existing concepts and select mathematical formulas [29].

The Mathematical Procedures Indicator assesses students' ability to apply appropriate mathematical steps to solve physics problems through the syntax of Digest, Expand, and Review. MURDER helps students systematically integrate experimental data and physics theory: from initial data processing (Digest), to the application of key formulas and calculations (Expand), to the evaluation of results and reflection on procedures (Review). Learning implications indicate that students are better able to follow procedures regularly and improve calculation accuracy, thus developing their mathematical skills conceptually [30].

The Logical Progression indicator assesses students' ability to organize problem-solving steps logically. MURDER encourages students to develop a coherent thought process, from experiment planning and causal analysis to evaluation of results. Observations indicate that students in the experimental class were able to consistently link theory to lab findings, strengthening their critical and logical thinking skills [29].

IV. Conclusions

Based on the research results, including data analysis and hypothesis testing, it can be concluded that the Mood, Understand, Recall, Digest, Expand, Review (MURDER) learning model significantly improves the problem-solving skills of grade XI science students on the topic of sound waves in the second semester of the 2024/2025 academic year. This is indicated by the t-test results, which show a t-count > t-table at the 5% significance level, as well as an increase in the average problem-solving score from 95.16 (control class) to 131.72 (experimental class), indicating a real improvement after implementing the MURDER model.

The effectiveness of this model is supported by the results of the instrument test, where Cronbach's Alpha reliability = 0.764, which falls within the high category, indicating that the instrument can be relied upon to measure problem-solving skills. Considering these findings, the MURDER model can be recommended for implementation in physics learning at one of the Madrasah Aliyah (Islamic high schools) in Tasikmalaya Regency, especially on topics such as waves, resonance, and other related physics concepts, to improve students' cognitive abilities and problem-solving skills in a systematic and structured manner.

Based on the results of this study, it is recommended that teachers use engaging stimuli in the early stages of learning, such as videos, images, or audio, to arouse students' interest and motivation. The MURDER model can be combined with virtual laboratories or bold simulations on other physics materials to enhance interaction and conceptual understanding. In contrast, the use of simulation software in the physics approach stage can strengthen students' problem-solving skills. Furthermore, the development of logistical thinking skills should be carried out through digital media, such as scientific writing, interactive videos, and bold discussions, so that students are accustomed to systematically constructing scientific arguments and procedures. For future research, it is recommended to use a more specific assessment rubric for each problem-solving indicator, as a clear, detailed rubric can improve score accuracy, minimize assessor subjectivity, and strengthen the validity and reliability of research results. Thus, the application of the MURDER model not only supports effective physics learning but also produces a more objective and comparable evaluation of problem-solving skills across studies.

This study has several limitations. First, its scope was limited to a single school and a single topic, so the results may not be fully representative of the broader population. Second, the relatively short study duration limited the ability to observe the long-term development of problem-solving skills. Third, varying student initial abilities and equitable access to technology in the classroom also pose challenges, particularly in the utilization of virtual laboratories or daring simulations. Therefore, future research is recommended to cover a broader population, consider a variety of materials, and adopt a longitudinal design or mixed-methods approach to obtain more comprehensive data. Furthermore, technology integration should be explained concretely, for example, through the use of a Learning Management System (LMS), PhET simulations, or daring collaborative platforms. Despite these limitations, this study makes an important contribution by demonstrating the effectiveness of the MURDER model in improving students' problem-solving skills in sound waves.

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