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Contextual Technology-Based Physics Module on Sound Absorption: Improving Critical Thinking Skills and Scientific Attitudes of Indonesian High School Students

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Abstract

The development of technology and science demands that education continues to innovate in enhancing students' critical thinking skills and scientific attitudes. One way to achieve this, specifically in physics education, is by developing practical modules that utilize experimental activities to foster critical thinking skills and scientific attitudes. This study aims to (1) develop a practical module on the sound absorption coefficient, (2) test the module's validity, (3) evaluate the practicality of the module in learning, and (4) assess the effectiveness of the module in improving students' critical thinking skills and scientific attitudes. This research employs an R&D approach, utilizing the 4D procedure: define, design, develop, and disseminate. Product trials were conducted using a pretest-posttest control group design. The results show that the developed practical module on the sound absorption coefficient has specific characteristics that integrate the measurement of physical parameters for technologies related to sound-absorbing materials, as well as excellent material and media validity, making it suitable for use and possessing a high level of practicality based on feedback from teachers and students. The module's readability test showed high ease for students in reading the content presented. Additionally, the module's effectiveness is demonstrated by significant improvements in critical thinking skills, with a N-gain of 0.85, and the achievement of scientific attitudes in students after using the practical module, with 79.54% of aspects achieved, which is higher compared to the group using conventional learning modules.

INTRODUCTION

In the 21st century, education is increasingly expected to equip students with skills that extend beyond content knowledge, emphasizing the ability to think critically, solve complex problems, communicate effectively, and engage in collaborative work [1], [2]. These competencies are essential for preparing individuals to thrive in a rapidly changing, technology-driven world. Science education, in particular, plays a crucial role in fostering these skills, as it naturally integrates inquiry, investigation, and evidence-based reasoning. Within this context, the teaching and learning of physics become especially important, given their strong foundation in empirical observation, experimentation, and analytical thinking.

As a branch of the natural sciences, physics studies natural phenomena through a scientific approach that includes observation, experimentation, and analysis [3], [4]. Students not only acquire knowledge in the form of facts, concepts, and principles in physics learning but also develop critical thinking skills and scientific attitudes through systematic and structured experimental processes. Science subjects, including physics, emphasize the scientific method, which involves observation, experimentation, and analysis, along with the development of scientific attitudes such as curiosity, perseverance, openness, and honesty [5], [6]. Based on this perspective, physics learning should consider experimental or practical activities.

One relevant experimental topic in physics is the sound absorption coefficient, which is a key aspect of the Sound Wave material. It is a measure that describes a material's ability to absorb sound wave energy [7], [8]. This phenomenon is essential to study, especially in the context of acoustics, for applications in both classrooms and broader environments, such as the design of spaces that require sound control [9]. However, despite the significance of this topic, teaching materials that link the concept of sound absorption coefficient in sound wave materials, particularly at the high school level, remain quite limited.

The primary goal of education in schools is to equip students with the skills necessary to face challenges in an ever-evolving world [10], [11]. One crucial skill is critical thinking, which involves the ability to analyze, evaluate, and draw conclusions from information objectively [12], [13], [14]. Additionally, scientific attitudes, including curiosity, openness, and precision, are vital components in learning that focus on the deep development of knowledge [3], [15], [16]. The importance of critical thinking skills and scientific attitudes cannot be separated from the learning process involving experiments. Experimental activities or practical work in schools provide students with the opportunity not only to test the theories they have learned but also to develop their analytical skills. Students are encouraged to plan, conduct, and systematically analyze experimental results [17], [18]. This process motivates them to think critically, evaluate various variables, and solve potential problems that may arise during experiments.

Several previous studies have developed various tools and practical modules to enhance students' critical thinking skills in physics education. For example, experiments on the coefficient of static friction have been used to improve students' understanding of force and friction concepts, as well as to develop their analytical skills [16]. Other research indicates that the use of the scientific method in experiments can strengthen students' scientific attitudes, such as curiosity, teamwork, and openness to unexpected experimental results [2], [19] However, despite the extensive development and application of experimental physics tools, teaching materials that focus on the sound absorption coefficient in sound wave materials for high school physics education are rarely found. Most existing studies focus more on conventional acoustic theory aspects, such as echo and reverberation phenomena, with few providing opportunities for students to engage in hands-on experiments that link acoustic theory to classroom practice. This suggests that learning activities targeting experiments to determine the sound absorption coefficient could be further developed, with an emphasis on enhancing students' critical thinking skills and scientific attitudes.

Other research indicates that practical activities organized in a guidebook or module for physics education can enhance students' critical thinking skills [20], [21]. Practical modules offer students the opportunity to think analytically, solve problems systematically, and reflect on the data they collect. Modules that link experiments with theory can offer a deeper and more applicable understanding while also encouraging students to think more critically when analyzing experimental results [22], [23]. Critical thinking skills are essential, as students must be able to investigate physical phenomena, plan experiments, and evaluate the data and conclusions drawn within the context of physics learning [24]. Critical thinking skills also include the ability to define problems, gather and evaluate data, and draw rational conclusions [21], [25].

A scientific attitude refers to the behaviors and attitudes required to conduct research and experiments systematically and objectively [26], [27]. It is crucial for developing skills in conducting experiments and analyzing scientific data in physics education. Scientific attitudes can be categorized into several aspects, including curiosity, respect for evidence, critical reflection, perseverance, creativity and inventiveness, open-mindedness, cooperation with others, willingness to tolerate uncertainty, and sensitivity to the environment [16], [28]. Simply put, scientific attitudes encompass curiosity, open-mindedness, creativity, collaboration, and a sense of responsibility. These attitudes are demonstrated when students show active engagement. Several studies indicate that experiential-based learning can enhance students' scientific attitudes [2], [26], [29], [30]. Through experimentation, students are provided opportunities to develop scientific attitudes, such as curiosity about natural phenomena, openness to unexpected results, and the ability to collaborate in group discussions and analyses [17].

The researcher conducted observations to identify the critical thinking skills and scientific attitudes of students at SMA Negeri 3 Semarang. The results of the observations indicated that the critical thinking skills and scientific attitudes of the 11th-grade students were relatively low. This was attributed to the use of conventional teaching methods, which tend to lead to passive learning. Furthermore, there was a lack of stimulation to develop critical thinking skills, as well as limited opportunities for students to engage in discussions and collaboration. Teacher feedback also emphasized the low student response during the learning process. Therefore, efforts are needed to enhance students' critical thinking skills and scientific attitudes in physics education at SMA Negeri 3 Semarang.

Based on this, the present study aims to develop a practical module on the sound absorption coefficient that students can use to conduct experiments, thereby strengthening their understanding of acoustics while also enhancing their critical thinking skills and scientific attitudes. Through this practical module, students will have the opportunity to observe, experiment, and analyze data directly, thereby developing scientific attitudes such as curiosity, open-mindedness, creativity, collaboration, and responsibility.

This study aims to investigate the impact of the practical module on students' learning of sound absorption coefficient while also examining its effect on students' critical thinking skills and scientific attitudes. In addition, the study aims to investigate the readability of the practical module on the sound absorption coefficient and to evaluate the responses provided by its users, specifically teachers and students.

RESEARCH METHODS

This study falls under the category of Research and Development (R&D). R&D research is a process aimed at developing and validating products [31]. The product produced in this study is a practical module on the Sound Absorption Coefficient intended to enhance students' critical thinking skills and scientific attitudes. The research procedure employs the Thiagarajan (4D) model, which consists of four stages: Define, Design, Develop, and Disseminate. The specifications for each of these stages are illustrated in Figure 1.

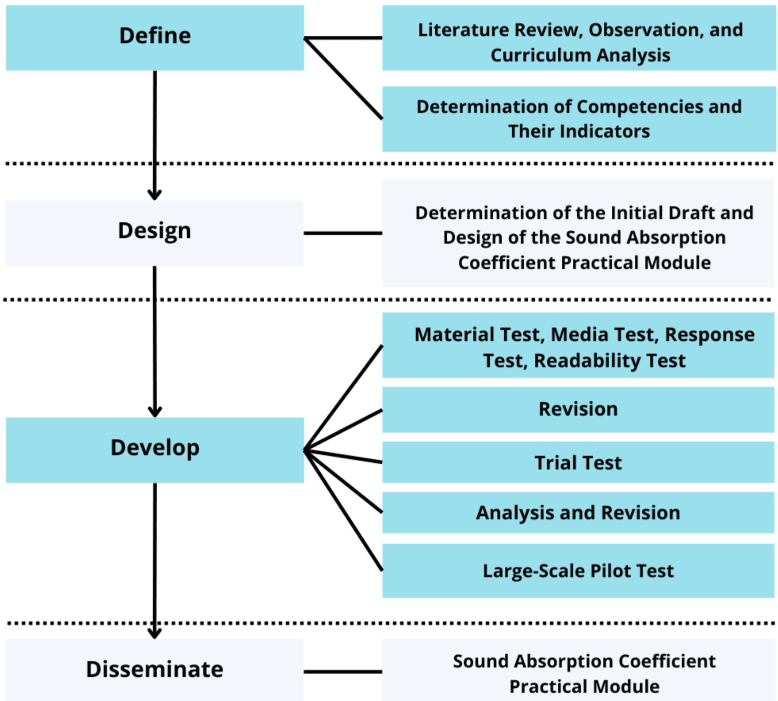

Figure 1. Stages of Development of the Sound Absorption Coefficient Practical Module

The definition stage in this study begins with observations at SMA Negeri 3 Semarang to assess the learning process, the use of learning media, as well as the conditions of students, teachers, and the school. The results from this stage are used to identify the needs that will form the basis for planning and developing the practical module. The focused needs include: (1) students' critical thinking skills and scientific attitudes as essential 21st-century skills, (2) students' basic competencies in analyzing the physical quantities of standing waves and traveling waves according to the Indonesian curriculum, and (3) the development of a media-based practical module that aligns with wave material and is presented contextually.

The design stage is the phase of planning or conceptualizing to find effective and efficient ways to structure a practical module based on the sound absorption coefficient. At this stage, the initial design of the material and product to be used in data collection is produced. The draft prepared during this stage includes basic competencies, material instructions, and concept maps. These three components will form the foundation for creating a comprehensive practical module.

The development stage is the implementation phase of the designed plan. The initial draft containing the material and product design is further developed at this stage. In the development phase, a feasibility test of the practical module is conducted, involving media experts and content experts to assess the feasibility of the media, as well as a response test conducted by practitioners or senior high school physics experts. Additionally, high school students carry out a readability test. The feasibility test, response test, and readability test aim to determine whether the developed practical module aligns with the expected needs and criteria. The research instruments used in this study include validation sheets, interview guidelines, observation sheets, tests to assess the readability of the practical module text, critical thinking skill tests, and Scientific Attitude Observation Sheets. Before being used, the instruments were tested, and the reliability coefficient for the critical thinking skill test was found to be 0.732, which is categorized as high.

The practical module, which had been validated for its content and feasibility, was subsequently implemented with 34 students in the experimental class and 34 students in the control class at SMA Negeri 3 Semarang. The sampling technique employed in this study was purposive sampling, where participants were selected based on specific criteria to align with the research objectives. Students were chosen because, first, they had not yet received instruction on the physics topic of sound waves, thereby minimizing the influence of prior knowledge on the study outcomes. Second, they had already completed learning about simple harmonic motion and mechanical waves, providing them with the necessary conceptual background to engage effectively with the module activities. This purposive approach was intended to create a controlled and focused setting for evaluating the impact of the practical module on students' critical thinking skills and scientific attitudes.

This study employed an experimental method with a pretest-posttest control group design to investigate differences in the acquisition of critical thinking skills and scientific attitudes among students. In the experimental class, students were given a practical module based on the sound absorption coefficient, whereas in the control class, students received conventional learning based on the Kurikulum Merdeka. The experimental design is illustrated in Figure 2.

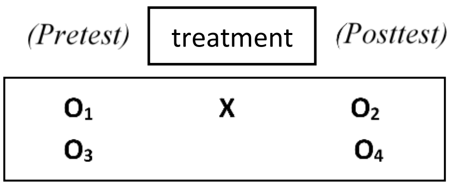

Figure 2. Pretest-Posttest Control Group design

Where,

O_1: Pretest scores of the Experimental Group Using Modul
O_2: Posttest scores for the Experimental Group Using Modul
O_3: Control group pretest scores using conventional teaching materials
O_4: Control group posttest scores using conventional teaching materials
X: Treatment using wave-assisted teaching materials with Modul

To control for potential external biases that could influence the results, several measures were implemented in this study. First, initial student abilities were considered by ensuring that both the experimental and control groups had similar academic backgrounds, particularly in prior physics topics such as simple harmonic motion and mechanical waves. Second, to minimize instructional variability, both groups were taught by the same teacher throughout the study, using the same classroom management approaches and assessment standards. This consistency was intended to reduce differences attributable to teaching style or teacher-student interaction. Through these controls, the study aimed to isolate the effects of the practical module intervention more accurately and ensure the validity of the comparative results between groups.

The critical thinking skills outlined in this study are based on Halpern's theory, which encompasses aspects such as Hypothesis Testing, Argument Analysis, Reasoning, Analysis of Possibilities and Uncertainty, Problem-Solving, and Decision-Making [24], [32]. The specific domain of the MCT test was adapted to develop several concrete indicators for essay tests, which are relevant to the analytical and experimental physics content, as shown in Table 1 [24]. Meanwhile, for the observation of scientific attitudes, aspects such as curiosity, open-mindedness, creativity, collaboration, and responsibility were adapted [16], [33]. These aspects are measured through observation, looking at observable indicators from the activities performed by students, as presented in Table 2.

Table 1. Aspects of Students' Critical Thinking Skills

Aspects of Critical Thinking	**Specific Domain in Science**	**Specific Domain in Sound Wave Material**
Hypothesis Testing	• Interpreting the relationship between variables.	• Developing hypotheses related to the relationship between frequency, amplitude, and wave speed.
	• Identifying relevant variables.	• Formulating hypotheses linking physical quantities of sound waves.
Argument Analysis	• Identifying claims and evidence in scientific arguments.	• Critiquing claims such as theories or arguments using experimental data.
	• Assessing the quality of evidence used.	• Evaluating evidence of the medium's influence on sound wave speed.
Reasoning	• Using deductive or inductive logic.	• Establishing cause-and-effect relationships between variables like frequency, amplitude, and sound wave speed.
	• Drawing conclusions based on experimental evidence.	• Concluding the relationship between temperature and sound wave speed in air.
Analysis of Possibilities and Uncertainty	• Identifying uncertainty in experiments.	• Identifying uncertainty in measuring sound wave speed.
	• Using statistics to measure uncertainty.	• Calculating errors in sound wave speed measurements.
Problem Solving and Decision Making	• Formulating alternative solutions based on evidence.	• Selecting the best solution for sound wave experiments, such as choosing the right medium or a more accurate measurement method.
	• Evaluating solutions and decisions made.	• Evaluating the best way to measure sound wave speed under different conditions.

Table 2. Aspects of Students' Scientific Attitude

Aspect of Scientific Attitude	**Indicator**	**Sub-Indicator**
Curiosity	• Paying close attention	• Giving full attention to the observed object or phenomenon.
		• Providing relevant responses to questions and opinions.
	• Asking new questions	• Asking relevant questions to further understand the phenomenon.

Aspect of Scientific Attitude	Indicator	Sub-Indicator
		• Confirming or seeking clarification on concepts that are not fully understood.
Open-mindedness	• Responding positively to opinions	• Expressing opinions or positions with well-founded and evidence-based arguments.
		• Respecting others' opinions even if they differ from personal views.
	• Accepting new knowledge and data discrepancies	• Not always feeling right and being willing to change views based on new data or evidence.
		• Accepting discrepancies between the obtained data and initial hypotheses or predictions.
Creativity	• Making a difference	• Creating new ideas or alternative ways to solve problems.
		• Seeking alternative solutions when experimental results do not meet expectations.
	• Designing new strategies	• Developing better experimental procedures based on obtained results.
Cooperation	• Designing strategies together	• Collaborating with group members to design strategies or experimental procedures.
		• Assigning clear roles and tasks within the group to achieve common goals.
	• Completing tasks	• Completing tasks on time and to the expected quality.
		• Actively participating in group discussions and contributing to decision-making.
Responsibility	• Paying close attention	• Ensuring that all tasks and experiments are performed correctly and according to procedures.
		• Being willing to correct mistakes if found during the experimental process.
	• Completing tasks	• Committing to completing tasks properly, according to the assigned portion and goal.
		• Being responsible for the results and completing tasks with full dedication.

The Dissemination stage was carried out by publishing the sound absorption coefficient practical module in several high schools in Semarang, Indonesia. Teachers at these schools were invited to use the module in their classroom instruction. The results of this research on the development of the practical module focus on impacting physics education, particularly in the development of students' critical thinking skills and scientific attitudes.

RESULTS AND DISCUSSION

The results of this research development are the Sound Absorption Coefficient Practical Module, along with the results of testing its validity, practicality, and effectiveness in enhancing critical thinking skills and science attitudes.

Characteristics of the Sound Absorption Coefficient Practical Module

The developed practical module focuses on enhancing students' critical thinking skills and scientific attitudes through experiments on sound absorption coefficients. This module is designed in accordance with the current curriculum and integrates 21st-century educational approaches, as well as the demands of Education 4.0. The primary objective of developing this module is to help students gain a deeper and more contextual understanding of physical phenomena occurring in their environment.

This practical module has several characteristics that support the improvement of students' critical thinking skills and scientific attitudes. First, the module utilizes available technology in the physics laboratory, including sound measurement devices and Android-based applications (such as Arduino Science Journal), to conduct experiments. Second, the module employs a contextual approach that links the material to real-world phenomena, allowing students to understand physics content more practically. Third, the module is designed to be used independently by students, both in and outside of class hours, allowing them to access and learn at their convenience, according to their individual needs.

This practical module is organized using a contextual approach designed to help students understand sound absorption phenomena in everyday life. This approach also supports the development of critical thinking skills, as students are not only required to follow the experimental procedure but are also asked to identify problems, formulate hypotheses, and systematically analyze the experimental results. At every stage of the experiment, students participate in group discussions and reflection on the results obtained to sharpen their analytical skills.

In addition to fostering critical thinking, this module is also designed to cultivate scientific attitudes in students, including curiosity, openness to new ideas, and the ability to work collaboratively in groups. By collaborating in groups, students can exchange information, discuss experimental results, and find solutions to challenges they encounter during the practical work. The reflection process and group discussions are expected to strengthen students' scientific attitudes, particularly in terms of perseverance, openness, and cooperation.

The module comprises several experimental steps that require students to gather data, analyze the results, and draw conclusions about the relationships between the variables involved. For instance, in the experiment on the sound absorption coefficient, students will be asked to measure the sound absorption levels of various materials that are familiar to them, making contextual learning more meaningful. These experimental steps help students think critically and scientifically. The stages of the experiments conducted by students during the practical session are presented in Figure 3. Therefore, this practical module not only provides interactive and enjoyable learning but also develops students' critical thinking skills and scientific attitudes, which are essential in physics education and everyday life.

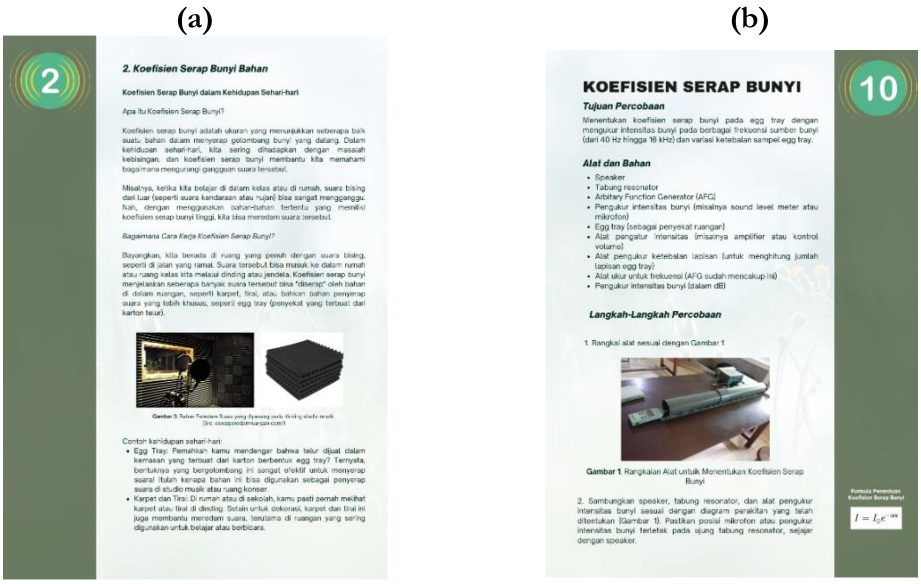

Figure 3. Contextual Approach: (a) Contextual Phenomenon (b) Practical Procedure

The Validity of the Sound Absorption Coefficient Practical Module

The validity of the developed sound absorption coefficient practical module was assessed by three validators, who are lecturers in the Physics Education Department at Semarang State University.

The validation process focused on the content, media, and foundational feasibility to enhance students' critical thinking skills and scientific attitudes. The feasibility of the content was evaluated in terms of its substance and language, while the feasibility of the media was assessed in terms of graphics and ease of use. Based on the validation results provided by the validators, several suggestions and inputs were offered for improvement before the module was trialed on a limited scale. The validation results of the sound absorption coefficient practical module, as conducted by the validators, are presented in Table 3.

Table 3. Validation Results of the Sound Absorption Coefficient Practical Module

Aspect	Validation Result Percentage (%)	V1	V2	V3
	Content Expert			
1. Content Feasibility	95.36	96.40	94.33	95,67
2. Language Feasibility	90.33	89.33	92.16	89.50
Average	92.85	92.86	93.24	89.50
Category	Very Valid			
	Media Expert			
1. Graphic Feasibility	90.37	91.33	89.45	90.33
2. Media Feasibility	89.08	89.67	87.91	89.67
Rata-Rata Ahli Media	89.72	90.50	88.68	90.00
Category	Very Valid			

Based on Table 3, it can be concluded that the practical module on the coefficient of sound absorption is highly valid in terms of content, with an average of 92.857%, which falls under the "very valid" category. The module also demonstrates a high validity in terms of media, with an average of 89.72%. Overall, this practical module on the coefficient of sound absorption is highly suitable for use in teaching and learning.

The Readability of the Sound Absorption Coefficient Practical Module

The practical module, which the validators have validated, was then tested on a limited scale, followed by a readability test. The readability test was conducted through a fill-in test and a readability questionnaire. The fill-in test consisted of 20% of the reading material from the module, or 14 pages, with every fifth word removed from the sentences. If the fifth word was a conjunction or preposition, the next word was selected. This test was administered to 15 students who had previously studied wave material. The test results indicated that the percentage of correct answers was 80.25%. Based on Bormuth's criteria for the readability of instructional materials, this result can be categorized as "very easy to understand." The results of the readability questionnaire administered to the students showed that the average readability percentage was 83.45%, indicating that students easily understand the Sound Absorption Coefficient Practical Module.

Student and Teacher Responses to the Practicality of the Sound Absorption Coefficient Practical Module

After the lessons were conducted, response questionnaires were distributed to students and teachers to gather insights into the practical impressions of using the Sound Absorption Coefficient Practical Module. The results of the questionnaires, assessing student and teacher responses to the practicality of the developed module, are presented in Tables 4 and 5.

Table 4. Results of Student and Teacher Responses to the Practicality of the Practical Module

Respondent	Percentage (%)
Student	88.57
Teacher	92.50

Table 5. Results of Student and Teacher Responses to the Practical Module in Large-Scale Trial

Respondent	Percentage (%)
Student	94.12
Teacher	94.00

The percentage response results from students and teachers in Table 4 show an average rating of "very good." However, there are still areas that need improvement, based on feedback from students and teachers, such as enhancing the color scheme and design to engage readers better. After revisions, the practical module was used in the large-scale trial. The response percentage results from the students and teachers in the large-scale trial, as shown in Table 5, indicate an average rating of "very good."

The Improvement of Students' Critical Thinking Skills through a Technology-Based Practical Module on Sound Absorption Coefficients in the Sound Wave Material

The enhancement of students' critical thinking skills through a technology-based practical module on sound absorption coefficients is evident in the results of a large-scale trial conducted in the 11th grade at SMA Negeri 3 Semarang, involving 68 students. The improvement in critical thinking skills in both the control and experimental classes is shown in Table 6.

Table 6. N-Gain Test Results for Critical Thinking Skills

Class	Average		N-Gain
	Pretest	Postest	
Control	21.50	46.50	0.32
Experiment	22.00	88.50	0.85

In Table 6, it is evident that the experimental class shows a higher improvement in critical thinking skills compared to the control class. The experimental class utilized a sound absorption coefficient practical module designed to provide a deeper understanding of sound wave phenomena through experiments conducted with the aid of available laboratory tools and technology. Based on the results obtained, the data distribution indicates that the data is regular and homogeneous, allowing hypothesis testing to be conducted using parametric statistical analysis or an independent t-test. The research hypotheses are as follows:

H_0: The improvement in critical thinking skills in the experimental class is less than or equal to the control class.

H_1: The improvement in critical thinking skills in the experimental class is greater than in the control class.

Table 7. t-Test Results for the Improvement of Critical Thinking Skills

Class	n	N-Gain	t_{hitung}	t_{tabel}
Control	34	0.32	16.276	1.997
Experiment	34	0.85		

Based on Table 7, it can be observed that the t-value exceeds the t-table value, indicating that it falls in the rejection region of the null hypothesis (H_0). Therefore, it can be concluded that the improvement in critical thinking skills in the experimental group is significantly greater than that in the control group. In other words, the use of the technology-based sound absorption coefficient practical module enhances students' critical thinking skills more effectively than the conventional practical module. Further analysis of the achievement of critical thinking skills in each aspect is presented in Table 8.

Table 8. Achievement of Critical Thinking Skills in Each Aspect

Aspect	Percentage (%)
Hypothesis Testing	75.44
Argument Analysis	74.92
Reasoning	82.58
Analysis of Possibilities and Uncertainty	85.41
Problem Solving and Decision Making	79.87

One effort to develop critical thinking skills is through the analysis of sound wave phenomena, which is then applied in experiments using a sound absorption coefficient practical module. The aspects of hypothesis testing, argument analysis, and analysis of possibilities and uncertainty are developed through the process of analyzing variables related to the sound wave phenomena in this experiment, as presented in the module. Furthermore, after the data is obtained, the aspects of hypothesis testing, reasoning, problem-solving, and decision-making are formed by providing problems that refer to the data from the conducted experiment. This process allows students to develop their thinking and ideas, utilizing critical thinking skills.

The use of technology in the laboratory, such as the measuring instruments available for the sound absorption coefficient experiment, enables students to perform direct measurements and view the results in real-time. This can stimulate students' critical thinking processes, as they are required to understand and analyze the data obtained from the experiment. This finding is consistent with previous studies, which have shown that technology-based experiments offer students opportunities to develop their critical thinking skills in a more contextual and applied setting [24], [34].

The sound absorption coefficient practical module, designed with clear procedures and technology-based methods, allows students to conduct experiments directly using the available tools and technology in the laboratory. This helps students better understand the abstract concept of sound wave phenomena, enabling them to connect theory with the practical applications carried out during the experiment.

Overall, the research results indicate that the use of the technology-based sound absorption coefficient practical module in sound wave learning has advantages in enhancing critical thinking skills compared to the conventional print-based learning modules. However, there are still some shortcomings in developing specific aspects of critical thinking skills, particularly in terms of engaging in deeper argumentation. This is further supported by the observation that, during the learning process, students tend to engage in activities such as analyzing hypotheses, analyzing data, and attempting to solve problems with various solutions without sufficiently considering perspectives that could strengthen their arguments.

Table 8 shows that the aspect of argument analysis has the lowest achievement percentage. The low achievement in argument analysis is due to the limited use of modules that require this skill. Students still struggle to explore various interpretations of sound wave phenomena presented in the form of arguments. As part of an improvement effort, a shift in students' mindset is necessary to enable them to think more logically, rationally, and systematically, thereby enhancing their argumentation skills. Additionally, the module content needs to be expanded to include various issues that involve argumentation in their discussions.

Scientific Attitudes of Students through the Sound Absorption Coefficient Practical Module on Sound Wave Material

This study aims to measure and analyze the improvement of students' scientific attitudes during the practical sessions using the sound absorption coefficient practical module on sound wave material at SMA Negeri 3 Semarang. The aspects of scientific attitude that were observed include curiosity, open-mindedness, creativity, cooperation, and responsibility, with indicators designed to assess students' attitudes during practical activities.

The results of the observations on students' scientific attitudes, measured during the practical activities, showed significant achievements in each aspect observed. The percentage of students' achievements in each element of their scientific attitude is presented in Table 9.

Table 9. Achievement of Students' Scientific Attitudes in Each Aspect

Aspects of Scientific Attitude	Percentage (%)
Curiosity	83.45
Open-Mindedness	70.21
Creativity	78.64
Cooperation	85.27
Responsibility	80.13
Average	79,54

The research results indicate that the application of the sound absorption coefficient practical module on sound wave material has led to high achievement in students' scientific attitudes, particularly in the aspects of cooperation and curiosity. In terms of collaboration, the achievement percentage reached its highest value at 85.27%. This indicates that technology-based practical activities conducted in groups encourage students to collaborate effectively in completing experiments. Students actively share responsibilities, discuss their observation results, and assist one another in designing experiments. This finding aligns with previous research, which has demonstrated that strong interaction among group members not only improves practical outcomes but also fosters a more enjoyable and effective learning environment [16], [35].

Such scientific attitudes are crucial because they demonstrate that students do not merely receive information passively but actively seek a deeper understanding. This indicates that with the presence of engaging and technology-based practical approaches, students can be trained to become more inquisitive and critical towards the phenomena they encounter. These findings also highlight the great potential of using technology to enrich the learning experience and foster stronger scientific attitudes among students.

This study has several limitations that should be acknowledged. First, the sample was limited to students who were already proficient in using instruments such as the AFG (Audio Frequency Generator) and dB meter, devices that are not commonly available in most schools. As a result, the generalizability of the findings may be restricted. Second, the observation of students' scientific attitudes was conducted during the learning process but may not have captured all classroom activities comprehensively due to the limited number of observers, consisting of only three individuals.

CONCLUSIONS

The sound absorption coefficient practical module developed in this study meets the criteria of validity and effectiveness as an instructional material for enhancing students' critical thinking skills, with an N-gain of 0.85, and fostering scientific attitudes, with 79.54% of aspects achieved. Students who used this practical module demonstrated greater improvements in critical thinking and scientific attitudes than those who used conventional instructional materials. Nevertheless, critical thinking and scientific attitudes still require further development. It is essential to acknowledge several limitations of this study that may impact the generalizability of the results. The sample was limited to students already proficient in using specific instruments, such as the Audio Frequency Generator (AFG) and dB meter, which are not widely available in most schools. Furthermore, the observation of scientific attitudes was constrained by the number of observers and may not have captured the full range of classroom activities. These factors suggest that caution should be exercised in extending the findings to broader educational contexts.

A recommendation for future research is to develop practical modules for other physics topics to improve students' critical thinking skills and scientific attitudes more comprehensively. Future studies should also consider broader sample populations and more extensive observation methods to address better aspects such as creativity, cooperation, and curiosity within experimental learning settings, thereby overcoming the limitations encountered in this study.

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