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DEVELOPMENT OF A STEAM-BASED MUSIC THERAPY BOX (BMT) FOR TEACHING WAVES AND OPTICS

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ABSTRACT

This study aimed to develop a STEAM-based Music Therapy Box (BMT) as a learning medium for the Waves and Optics course and to evaluate its feasibility and effectiveness in enhancing students' conceptual understanding. The research employed a Research and Development (R&D) approach using the ADDIE model, which consists of the analysis, design, development, implementation, and evaluation stages. A limited field trial involved 30 students from the Physics Education Study Program at Universitas HKBP Nommensen. Data were collected through expert validation sheets, conceptual understanding tests, observation forms, and student response questionnaires. The results indicated that the developed BMT was highly feasible for instructional use. Its implementation improved students' conceptual understanding, as evidenced by an N-Gain score of 0.65 (moderate category) and a statistically significant difference between pretest and posttest scores ($p<0.05$). Student learning activities and responses were also rated very positively. These findings suggest that integrating music, sensor technology, experimental activities, and the STEAM approach can foster more contextual, interactive, and meaningful learning experiences.

Keywords: Music Therapy Box; STEAM; Waves and Optics; Learning Media; Conceptual Understanding

INTRODUCTION

Educational transformation in the digital age demands learning that facilitates the development of 21st-century competencies, such as critical thinking, creativity, collaboration, communication, and problem-solving skills. These changes are driving a paradigm shift in learning from a teacher-centered approach toward learning that provides students with opportunities to construct knowledge through active and meaningful learning experiences. In physics education, the learning process is not only directed toward mastering concepts but also toward the ability to connect these concepts with phenomena that occur in everyday life (Freeman et al., 2014; Rohmah et al., 2025).

The nature of physics which integrates abstract concepts, mathematical representations, and empirical phenomena requires the use of learning strategies that help students construct a comprehensive understanding. Learning that relies solely on verbal explanations is often insufficient to explain complex physical phenomena. According to Mayer (2021), conceptual understanding develops more effectively when information is presented through various complementary representations. The integration of visual and auditory elements, along with exploratory activities, enables learners to build stronger mental representations, thereby making the learning process more effective (Mayer & Fiorella, 2022).

The constructivist perspective also positions learning experiences as the foundation for knowledge formation. Piaget (1972) explained that understanding develops through interactions between individuals and their learning environment, while Vygotsky (1978) emphasized the importance of social experiences and collaborative activities in the process of knowledge construction. Therefore, physics education requires a learning environment that allows students to observe, explore, and interpret phenomena directly so that the concepts studied are understood not only theoretically but also contextually.

The Waves and Optics course is one of the foundational courses that plays a crucial role in building the conceptual foundation of students in the Physics Education Program. The material covered includes wave characteristics, frequency, resonance, interference, sound intensity, and various optical phenomena that require abstract and analytical thinking skills. The complexity of this material often poses challenges because students must simultaneously connect mathematical and visual representations with physical phenomena. Redish (2003) states that understanding of physics concepts develops optimally when students have the opportunity to connect various conceptual representations through integrated learning experiences.

Preliminary observations of students in the Physics Education Program at HKBP Nommensen University indicate that some students still struggle to explain the relationship between frequency and pitch, the phenomenon of resonance, and the application of sound wave concepts in everyday life. These difficulties result in a limited ability to connect theoretical concepts with observed real-world phenomena. Similar findings were reported by Harefa (2022), who noted that physics education at the university level still faces challenges in enhancing conceptual understanding when not supported by media capable of presenting concepts in a concrete and contextual manner.

Various studies have developed innovative learning media to improve the quality of physics education. Interactive multimedia based on Scratch has been shown to improve student learning outcomes through more engaging and interactive presentation of material (Ma'rifah et al., 2023). The development of Android-based mobile learning provides flexibility in learning about sound and light waves (Milinia et al., 2022). PhET-based virtual simulations have also been reported to be effective in helping students visualize abstract concepts, thereby improving their understanding of wave and sound concepts (Kristianto et al., 2023; Ningsih et al., 2023). Furthermore, the development of Problem-Based Learning (PBL)-based digital worksheets (E-LKPD) shows potential in enhancing critical thinking skills through structured problem-solving activities (Duri et al., 2024).

Developments in physics education research indicate an increasing use of the STEAM (Science, Technology, Engineering, Arts, and Mathematics) approach as a learning framework that integrates various disciplines into a holistic learning experience. The STEAM approach provides students with the opportunity to understand scientific concepts through activities that are more contextual, creative, and oriented toward solving real-world problems (Yakman & Lee, 2012). A systematic review conducted by Fitria et al. (2023) indicates that the implementation of STEAM in physics instruction positively contributes to enhancing creativity, critical thinking skills, and conceptual understanding. These findings are supported by research by Rohmah et al. (2025) and Rahayu et al. (2025), who reported that STEAM-based learning can support the development of 21st-century skills through collaborative and project-based learning activities.

Music is a phenomenon closely related to the concept of sound waves. The characteristics of pitch, frequency, amplitude, resonance, and sound intensity can be explained through the underlying principles of physics. In addition to serving as a learning context, music is also known to influence concentration, attention, and comfort during learning. Schellenberg (2005) reported that musical activities are associated with the development of cognitive abilities and information processing. Research by Khalisah et al. (2025) shows that music can help improve concentration during learning, while Khoirot et al. (2024) found that instrumental music contributes to increased attention among students during the learning process. A study conducted by Herdianti et al. (2024) also indicates that music therapy has a positive impact on focus and comfort while learning.

Recent studies have demonstrated the potential of various digital media to improve physics learning. Scratch-based interactive multimedia has been reported to support student engagement and learning outcomes (Ma'rifah et al., 2023), while Android-based mobile learning offers greater flexibility in studying sound and light waves (Milinia et al., 2022). Similarly, PhET-based virtual laboratories help students visualize abstract wave phenomena and improve conceptual understanding (Kristianto et al., 2023; Ningsih et al., 2023). Despite these benefits, most existing media remain screen-based and provide limited opportunities for students to interact with physical devices, conduct hands-on experiments, and analyze real-time measurement data.

The STEAM approach offers a broader framework for integrating scientific concepts, technology, engineering design, artistic elements, and mathematical analysis into meaningful learning activities. Previous studies have shown that STEAM-based physics learning can promote creativity, critical thinking, and other twenty-first-century skills (Rohmah et al., 2025). However, its implementation has rarely incorporated music as both an artistic element and a contextual representation of sound-wave concepts. Meanwhile, studies on music have primarily examined its contribution to concentration and learning comfort (Khalisah et al., 2025; Khoirot et al., 2024) or its therapeutic effects on psychological and physiological conditions (Batubara et al., 2021; Waruwu et al., 2023). These studies have not positioned music as an experimental context for learning physics.

The existing literature therefore reveals a fragmented research landscape. Digital physics media generally emphasize visual representations and virtual simulations, STEAM-based learning focuses mainly on interdisciplinary projects, and music-related studies concentrate on cognitive or therapeutic outcomes. Limited research has integrated music, sound-wave concepts, sensor technology, real-time data visualization, and hands-on experimentation into a single physics learning medium. Addressing this gap is important because such integration may help students connect abstract concepts, including frequency, resonance, amplitude, and sound intensity, with directly observable phenomena.

Accordingly, this study aims to develop and evaluate the feasibility and preliminary effectiveness of a STEAM-based Music Therapy Box (BMT) for the Waves and Optics course. The developed medium integrates musical stimuli, sensors, a microcontroller, a digital display, and experimental activities to provide a concrete, interactive, and contextual learning experience. The novelty of this study lies in positioning music not only as an auditory stimulus but also as a physics phenomenon that can be measured, analyzed, and interpreted through STEAM-based activities to strengthen students' conceptual understanding.

METHOD

This study employed the Research and Development (R&D) method using the ADDIE model (Analysis, Design, Development, Implementation, Evaluation) to develop a STEAM-based Music Therapy Box (BMT) learning medium for the Waves and Optics course. The ADDIE model was chosen because it provides a systematic development framework ranging from needs identification to product evaluation, making it suitable for the development of learning media (Sugihartini & Yudiana, 2018). The effectiveness of the developed media was subsequently evaluated through a limited pilot test using a One-Group Pretest–Posttest design.

Development of the BMT Learning Resource

The development of the learning material followed the five stages of the ADDIE model, which include needs analysis, product design, prototype development, implementation, and evaluation. A summary of the activities in each stage is presented in Table 1. The analysis phase focused on identifying learning needs, student characteristics, learning outcomes, and conceptual difficulties in the Waves and Optics material. The information obtained served as the basis for developing the media design and research instruments. The design phase produced preliminary designs for the media, learning tools, and data collection instruments. The development phase included the creation of a BMT prototype, validation by physics subject matter experts and instructional media experts, and product revisions based on validators' feedback. The implementation phase involved the use of the instructional media in the classroom, while the evaluation phase was conducted through an analysis of the implementation results to produce a final product suitable for use.

The BMT Media is designed as a STEAM-based learning tool that integrates the concepts of sound waves, sensor technology, experimental activities, and music into a single learning system. The main components of the media and their functions are shown in Figure 1.

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Table 1. Stages of Music Therapy Box (BMT) Development Using the ADDIE Model

Stage	Main Activities	Output
Analysis	Analysis of learning needs, student characteristics, learning outcomes, and wave and optics material	Media needs and product specifications
Design	Design of media, learning tools, research instruments, and STEAM-based activities	Preliminary design of media and instruments
Development	Media production, expert validation, revision, and product refinement	Preliminary validated products
Implementation	Testing the media on students and collecting research data	Data from the implementation
Evaluation	Analysis of research results and product refinement	Final product and recommendations for development

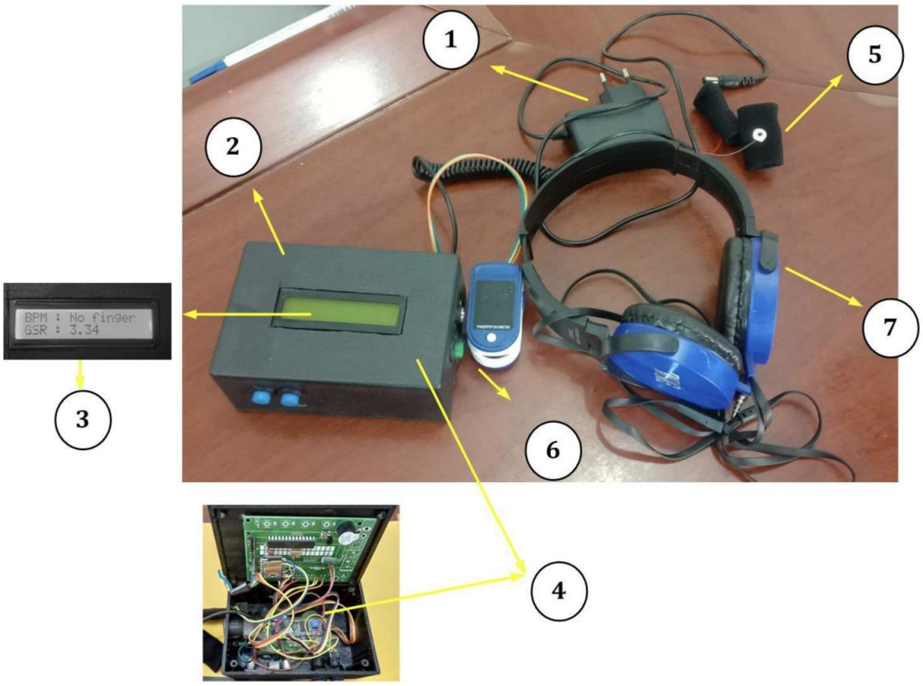

Figure 1: The developed Music Box

The Music Therapy Box (BMT) is a STEAM-based learning tool developed to help students understand the concepts of frequency, resonance, sound intensity, and the visual representation of measurement results in the Waves and Optics course. This tool integrates an audio system, sensors, a microcontroller, and a digital display so that students can directly observe the relationship between sound stimuli and the system's response.

Component descriptions in Figure 1:

1. An adapter serves as the power source.
2. A mini box made of HDPE serves as a housing and protective case for the electronic system.
3. LCD (*Liquid Crystal Display*) as a medium for displaying measurement results.
4. Arduino Uno (ATmega328) as the control and data processing center.
5. GSR (*Galvanic Skin Response*) sensor as a sensor for user response to audio stimuli.

6. MPX5050DP sensor as a pressure sensor used to detect changes in response during media use.
7. Headphones as the audio output device that generates sound stimuli.

Table 2. Specifications of the Music Therapy Box (BMT) Components

No	Component	System Function	Relevance to Learning
1	Adapter	Supplies electrical power	Demonstrates the principle of electrical energy conversion
2	HDPE Mini Box	Protects and organizes system components	Supporting *engineering* product design
3	LCD Display	Displays measurement results	Visualizing observation data
4	Arduino Uno (ATmega328)	Processing sensor data and controlling the system	Application of technology in physics education
5	GSR Sensor	Detecting user responses to audio stimuli	Linking learning activities with data analysis
6	MPX5050DP Sensor	Measures changes in pressure received by the system	Demonstrating the measurement process using the sensor
7	Headphones	Generates sound and music stimuli	Exploring sound frequency, resonance, and intensity

The media's operating principle begins with sound transmission via the music player module and speakers. The sound sensor detects the characteristics of the generated sound; the data is then processed by the Arduino Uno and displayed on the LCD. This mechanism allows students to observe the relationship between frequency, resonance, amplitude, and sound intensity directly through experimental activities. The effectiveness of the teaching aid was evaluated using a One-Group Pretest-Posttest design, as shown in Equation (1).

$$O_1 \ X \ O_2 \tag{1}$$

Notes:

O_1: pretest of conceptual understanding

X: learning using Music Therapy Box (BMT)

O_2: posttest of conceptual understanding

This design was used to identify changes in students' conceptual understanding after the use of the BMT medium by comparing pretest and posttest scores. A limitation of this design is the absence of a control group, so the results obtained cannot yet be directly compared with other learning models. The study population consisted of students in the Physics Education Program at HKBP Nommensen University who were taking the Waves and Optics course during the even semester of the 2025/2026 academic year. The research sample consisted of 30 students selected using purposive sampling based on the following criteria: (1) active students enrolled in the Waves and Optics course, (2) students who had already studied basic wave concepts, (3) students who attended the entire learning sequence, and (4) students who completed both the pretest and posttest in full.

The media was implemented over three sessions, with a time allocation of 3 SKS or the equivalent of 150 minutes per session. The first session focused on introducing the media and exploring the basic concepts of sound waves; the second session focused on experiments on resonance and sound intensity using the BMT; and the third session focused on analyzing the relationship between music and sound waves, administering the posttest, and completing the questionnaire. Details of the learning activities are presented in Table 3.

Table 3. Stages of BMT Media Implementation

Session	Activity	Output
I	Pretest, introduction to the media, demonstration of BMT use, and initial exploration	Data on students' initial abilities
II	Exploration of the concepts of frequency, resonance, and sound intensity through STEAM-based activities	Student activity data
III	Integration of wave and optics concepts, discussions, posttests, and completion of response questionnaires	Student learning outcomes and response data

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The research data were obtained through a concept comprehension test, student activity observation sheets, and a student response questionnaire. The concept comprehension test consisted of 20 multipletion questions covering the indicators of frequency, resonance, interference, sound intensity, and the relationship between music and sound waves. Student activities were observed by two observers during the learning process, while student responses were measured using a questionnaire containing 20 statements on a five-point Likert scale.

The content validity of all instruments was evaluated by two validators, consisting of a physics subject matter expert and an instructional media expert. The reliability of the instruments was analyzed using Cronbach's Alpha coefficient with a criterion of $\alpha \geq 0.70$ (Hair et al., 2019). Before being used in the study, the test items were also analyzed based on difficulty level and discriminative power to ensure the quality of the instruments. A summary of the research instruments is presented in Tables 4 and 5.

Table 4. Instruments Used

Instrument	Instrument Format	Number of Items	Indicators Measured	Data Source
Concept Comprehension Test	Multiple Choice	20 questions	Frequency and period, sound resonance, sound intensity, wave interference, transverse and longitudinal waves, and the relationship between music and sound waves	Students
Activity Observation Sheet	Observation Sheet	6 aspects	Participation in discussions, use of media, experimental practice, group collaboration, scientific communication, and enthusiasm for learning	Observer
Student Response Questionnaire	Likert scale (1–5)	20 questions	Media appeal, ease of use, learning motivation, concentration during learning, conceptual understanding, learning interactivity, and the effectiveness of music therapy	Students

Table 5. Conceptual Understanding Test Blueprint

Indicator	Question Number	Number
Frequency and Wave Period	1–3	3
Sound Resonance	4–7	4
Sound Intensity and Amplitude	8–10	3
Wave Interference	11–13	3
Transverse Waves and Longitudinal Waves	14–17	4
The Relationship Between Music and Sound Waves	18–20	3
Total		20

Data on expert validation results, student activities, and student responses were analyzed using descriptive statistics in the form of percentages and rating categories. Improvements in conceptual understanding were analyzed using Normalized Gain (N-Gain). Before hypothesis testing was conducted, the pretest and posttest data were tested for normality using the Shapiro–Wilk test. Differences between pretest and posttest scores were analyzed using a paired-sample t-test at a significance level of 0.05. The results of the analysis were used to evaluate the suitability of the medium and the effectiveness of BMT implementation in supporting students' conceptual understanding in the Waves and Optics course.

RESULTS AND DISCUSSION

The research instruments were validated by two validators, consisting of a physics subject matter expert and an instructional media expert. Additionally, the reliability of the instruments

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was analyzed using Cronbach's Alpha. The results of the instrument validity and reliability are presented in Table 6.

Table 6. Results of Instrument Validity and Reliability

Instrument	Validity (%)	Category	Cronbach's Alpha	Category
Concept Comprehension Test	89.75	Highly Valid	0.84	Reliable
Activity Observation Sheet	92.50	Highly Valid	–	–
Student Response Questionnaire	91.25	Highly Valid	0.88	Reliable
Average	**91.17**	**Highly Valid**	**0.86**	**Reliable**

Based on Table 7, all instruments were categorized as highly valid with an average validity of 91.17%. The reliability test results showed that the concept comprehension test and the student response questionnaire had Cronbach's Alpha values greater than 0.70, thus they were deemed reliable and suitable for use in this study. The suitability of the Music Therapy Box (BMT) media was evaluated by two validators, consisting of one physics subject matter expert and one educational media expert. The assessment covered the media's visual presentation, audio quality, content appropriateness, ease of use, interactivity, usefulness, integration of music and waves, and the application of the STEAM approach. The media validation results are presented in Figure

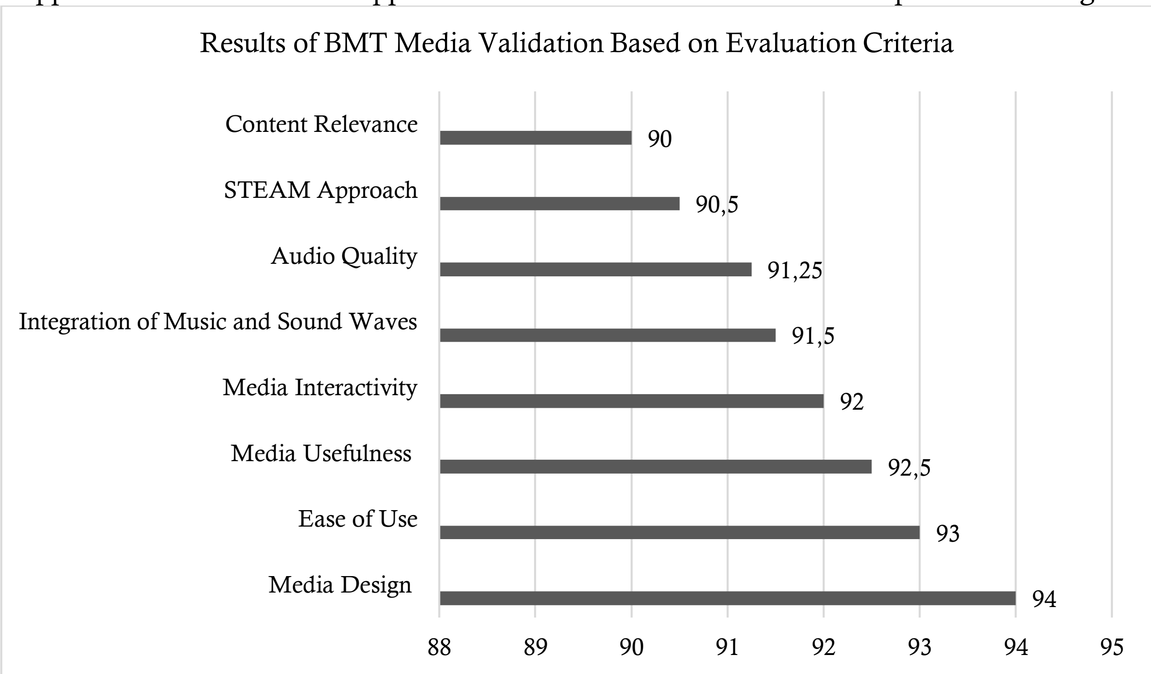

Figure 2. Percentage of BMT Media Validation Results Based on Evaluation Aspects

Based on Figure 2, the BMT media received an average score of 91.72%, falling into the "highly suitable" category. The highest score was obtained in the usefulness aspect at 94.00%, while the lowest score was obtained in the content relevance aspect at 90.00%. Nevertheless, all evaluation aspects fell into the "highly suitable" category. The validation results show that the developed media met the feasibility criteria in terms of both content and media. Furthermore, no aspect received a score below 85%, so the media was deemed suitable for use in the learning implementation phase after refinements based on the validators' feedback.

Several improvements were made before the media was used in the implementation phase. The revisions included refining the layout of components on the media panel, improving the display of information on the LCD, adjusting the user instructions, and refining the integration of Waves and Optics material into learning activities using the BMT. After the revisions were made, the media was deemed suitable for use in the learning pilot phase. Student learning outcomes were measured using a concept comprehension test administered before (pretest) and after (posttest) instruction using the Music Therapy Box (BMT) media. An analysis was conducted to determine the improvement in students' conceptual understanding following the implementation of the media.

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Table 7. Student Learning Outcomes and Statistical Analysis

Component	Pretest	Posttest	Description
Mean ± SD	46.67 ± 9.12	81.33 ± 7.25	Increased
Highest Value	65	90	Increased
Lowest Value	25	60	Increasing
Shapiro–Wilk Sig.	0.117	0.089	Normal
t-value	–	-12.876	Significant
Sig. (2-tailed)	–	0.000	p < 0.05
N-Gain	–	0.65	Moderate

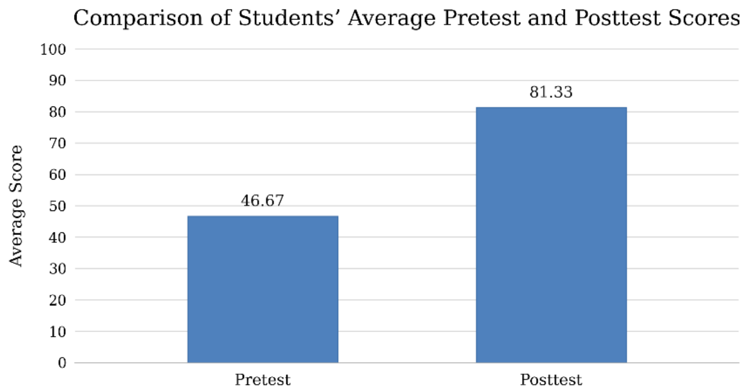

Figure 3. Comparison of Students' Average Pretest and Posttest Scores

Based on Table 8 and Figure 3, students' average learning outcomes increased from 46.67 ± 9.12 on the pretest to 81.33 ± 7.25 on the posttest. The highest score increased from 65 to 90, while the lowest score increased from 25 to 60. The results of the normality test indicated that the pretest and posttest data were normally distributed, with significance values of 0.117 and 0.089, respectively. The results of the paired-sample t-test showed a significance value of 0.000 ($p < 0.05$), indicating a significant difference between the pretest and posttest scores. Additionally, a Normalized Gain (N-Gain) value of 0.65 indicates that the improvement in students' conceptual understanding following the use of the BMT medium falls into the moderate category

Table 8. Improvement in Conceptual Understanding Based on Indicators

Conceptual Understanding Indicators	Pre-test	Posttest	N-Gain	Category
Frequency and Period	58.20	86.40	0.67	Moderate
Sound Resonance	54.30	85.70	0.69	Moderate
Sound Intensity	52.50	82.10	0.62	Moderate
Wave Interference	55.00	83.50	0.63	Moderate
Transverse and Longitudinal Waves	59.10	84.90	0.63	Moderate
The Relationship Between Music and Sound Waves	59.50	88.80	0.72	High

To obtain a more detailed picture of the improvement in students' conceptual understanding, an analysis was conducted on each indicator of the Waves and Optics material as measured by the conceptual understanding test. The analysis results are presented in Table 8 and Figure 4. Based on Table 8 and Figure 4, all indicators showed an increase in conceptual understanding after the implementation of the BMT media. The N-Gain values ranged from 0.62 to 0.72, indicating a moderate to high level of improvement. The highest improvement was observed in the indicator of the relationship between music and sound waves, with an N-Gain value of 0.72, while the lowest improvement was observed in the indicator of sound intensity, with an N-Gain value of 0.62. These results indicate that the use of BMT media made a positive contribution to students' understanding across all measured indicators.

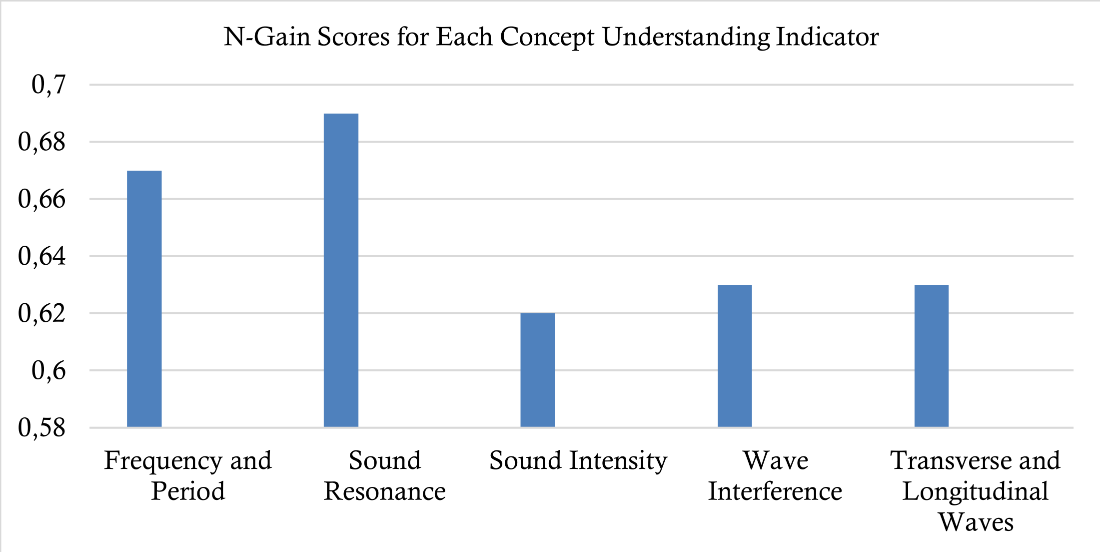

Figure 4. N-Gain values for each indicator of students' conceptual understanding after the use of the BMT media.

Student activities during the learning process were observed using observation sheets filled out by two observers at each session. Additionally, student responses to the use of the Music Therapy Box (BMT) were gathered through a questionnaire administered after the entire learning sequence was completed. A summary of the observation and questionnaire results is presented in Figure 5

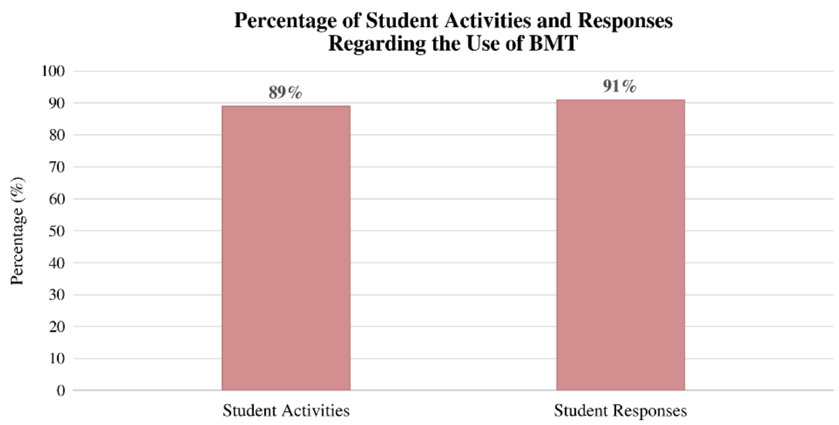

Figure 5. Percentage of Student Activities and Responses to the Use of BMT

Based on Figure 5, student activity during learning sessions using the BMT media achieved a percentage of 89.38% and fell into the "very good" category. The observation results showed that students were actively engaged in various learning activities, such as observing how the media worked, conducting simple experiments, discussing in groups, and presenting their observations during the learning process. Student responses to the use of BMT media achieved a percentage of 91.43%, falling into the "very good" category. The survey results indicate that students responded positively to the use of the media in the Waves and Optics course. The media was rated as engaging, easy to use, and effective in helping students understand the concepts being studied through a more interactive learning experience. Overall the results of the observations and questionnaires indicate that the BMT media received a high level of acceptance from students and effectively supported student engagement throughout the learning process. Overall, the research results show that the Music Therapy Box (BMT) media has a very good level of feasibility, is capable of improving students' conceptual understanding, and receives positive responses from users. These findings serve as the basis for further discussion regarding the contribution of BMT media to the teaching of Waves and Optics.

The quality of the instruments determines the accuracy of the data used to evaluate the effectiveness of a learning product. The validation results show that all instruments fall into the "highly valid" category with an average percentage of 91.17%, while the Cronbach's Alpha values for the conceptual understanding test and the student response questionnaire are above the minimum threshold of 0.70. According to Hair et al. (2019), these values indicate good internal consistency, making the instruments suitable for use as measurement tools in educational research. The presence of valid and reliable instruments provides a strong foundation for objectively interpreting the results of the media's implementation.

The media feasibility evaluation resulted in a "highly feasible" category with an average rating of 91.72%. The high rating in the usefulness aspect indicates that the multimedia learning tool (BMT) is capable of bridging abstract physics concepts, making them easier to grasp through concrete learning experiences. The integration of visual displays, auditory stimuli, and experimental activities allows students to acquire information through various representational channels simultaneously. These characteristics align with the Cognitive Theory of Multimedia Learning, which explains that learning becomes more effective when information is presented through complementary representations, thereby aiding the process of organizing and integrating knowledge into long-term memory (Mayer, 2021; Mayer & Fiorella, 2022). The combination of visual and auditory representations in the BMT provides students with the opportunity to build stronger connections between theoretical concepts and observed phenomena during the learning process.

The product's feasibility is further supported by the application of the STEAM approach, which integrates various disciplines into a single learning activity. The concepts of waves and sound serve as the science component; the use of Arduino and sensors represents the technology component; the tool-design process reflects the engineering component; music serves as the arts component; and the analysis of measurement results represents the mathematics component. This integration creates a more authentic learning experience closely aligned with the application of physics in everyday life. These findings support the research results of Rohmah et al. (2025) and Yakman and Lee (2012), which affirm that STEAM-based learning can strengthen creativity, critical thinking skills, and conceptual understanding through interdisciplinary connections. Various previous studies have developed interactive multimedia, virtual laboratories, and computer-based simulations to support physics learning (Kristianto et al., 2023; Ningsih et al., 2023). BMT offers a distinct approach by integrating music, sound sensors, and hands-on experimental activities into a single learning tool. This approach constitutes the primary contribution of this study, as the concept of sound waves is explored not only through visual simulations but also through auditory experiences that can be directly observed and analyzed.

Analysis of learning outcomes revealed an increase in conceptual understanding following the use of BMT. The significant difference between pretest and posttest scores indicates that media-assisted learning makes a tangible contribution to the mastery of concepts in Waves and Optics. The N-Gain score in the moderate category indicates that students experienced meaningful conceptual development during the learning process. These results are related to the characteristics of the learning process, which provided students with opportunities to observe, explore, and interpret physical phenomena directly. Experimental activities integrated into the use of BMT allow students to connect theoretical concepts with observational data, ensuring that the learning process does not stop at merely memorizing concepts. Knowledge is constructed through experience and interaction with the learning environment, as explained in the constructivist theory proposed by Piaget (1972) and Vygotsky (1978).

The use of music as a learning context further strengthens the concept-formation process. Frequency, resonance, amplitude, and sound intensity are no longer studied as symbols or formulas detached from daily life but are observed through phenomena familiar to students. The connection between music and sound waves facilitates the linking of abstract concepts to real-world experiences, making the concepts easier to understand and remember. Empirical support for the use of music in the learning process has been reported by several previous studies. Khalisah et al. (2025) found that music contributes to improved concentration during learning, while Khoirot et al. (2024) reported increased student attention when learning was accompanied by instrumental music. Schellenberg (2005) also explained that musical activities are related to the development of cognitive abilities and information processing. These findings reinforce the argument that music not only serves as a form of entertainment but can also be utilized as a pedagogical context to support physics learning.

Analysis based on indicators shows that the greatest improvement occurred in the material on the relationship between music and sound waves. This pattern indicates that students find it easier to understand concepts when the material is presented through a context that can be directly observed. Redish (2003) explains that understanding of physics develops more strongly when students are able to connect mathematical and visual representations with physical phenomena within a single learning experience. These characteristics are reflected in the use of BMT, which combines visual and auditory representations with experimental activities. The results of this study reinforce the findings of Ma'rifah et al. (2023), Kristianto et al. (2023), and Ningsih et al. (2023), who reported the effectiveness of interactive media in enhancing the understanding of physics concepts. The main difference lies in the use of music and sound sensors as an integral part of the learning process, thereby providing students with a richer multisensory learning experience compared to approaches based solely on visual simulations.

The success of implementing instructional media is determined not only by improvements in learning outcomes but also by the level of user engagement and acceptance during the learning process. The percentage of student activities and responses falling into the "very good" category indicates that the BMT is capable of creating a learning environment that encourages active participation. Learning activities involving observation, experiments, group discussions, and data interpretation provide space for students to take on the role of active learners. This approach aligns with the concept of active learning, which positions students as the primary agents in the process of knowledge construction. Bonwell and Eison (1991) explain that active student engagement contributes to improved conceptual understanding and higher-order thinking skills. Freeman et al. (2014) also reported that active learning strategies yield better academic outcomes compared to conventional learning in the fields of science and engineering.

The positive feedback from students indicates that the BMT is easy to use, engaging, and relevant to their learning needs. The integration of music, sensor technology, and data visualization creates a learning experience distinct from conventional instruction. Positive perceptions of the medium have the potential to boost learning motivation and strengthen student engagement throughout the learning process. These findings support the results of a study by Ma'rifah et al. (2023), which showed that the interactive learning medium can increase students' motivation and engagement through a more engaging and meaningful learning experience. High activity levels, positive responses, and consistent improvements in learning outcomes indicate that BMT is well-received as a STEAM-based physics learning medium. The integration of physics concepts, sensor technology, experimental activities, and music creates a learning environment that is more contextual, interactive, and relevant to the characteristics of college students.

Interpretation of the research results must take the study design into account. The media trial was conducted using a one-group pretest-posttest design without a control group; therefore, the effectiveness of the media cannot yet be directly compared with other learning models. Implementation was also limited to a single class with a small number of students. This scope limits the generalizability of the results to a broader population. Future research could include a control group, a larger sample size, and the application of the media to other physics topics to obtain more comprehensive empirical evidence regarding the effectiveness of BMT.

CONCLUSION

The development of the STEAM-based Music Therapy Box (BMT) has produced a learning medium that meets the criteria for being highly suitable for use in the Waves and Optics course. The integration of physics concepts, sensor technology, music, and experimental activities provides a more concrete learning experience, allowing students to directly observe and interpret

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sound wave phenomena. These characteristics support a more interactive learning process and provide students with the opportunity to build understanding through authentic learning experiences. The implementation of this learning material demonstrates a positive contribution to improving students' conceptual understanding. The improvement in learning outcomes observed after using the BMT indicates that presenting concepts through a combination of visual and auditory representations, along with hands-on laboratory activities, helps students connect theory with real-world phenomena. Furthermore, the high level of student activity and engagement suggests that the material creates an engaging learning environment, encourages active participation, and enhances student involvement throughout the learning process. The contribution of this research lies in the development of instructional media that integrates elements of Science, Technology, Engineering, Arts, and Mathematics (STEAM) into a single, integrated learning tool. The use of music as a learning context provides a new alternative for explaining the concept of sound waves while enriching innovations in physics learning media at the university level. Future development can focus on applying this media to other physics topics, involving a broader range of participants, and using a research design that allows for comparison with other learning models to obtain more comprehensive empirical evidence.

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