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Effectiveness of Multimodel Electronic Teaching Materials on Mechanical Waves to Enhance Problem-Solving Skills

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Abstract

This multimodel-based electronic teaching material is one of the innovations in supporting learning development to train problem-solving skills. The purpose of this study is to provide effective multimodel-based electronic teaching materials for use in learning. The ADDIE model is used in the research design which is a project of research and development. A total of 22 students of class XI MIPA 2 became the test subjects of this study. Data were obtained from the results of students' cognitive learning. Quantitative descriptive analysis was used for data analysis. The electronic teaching materials obtained were: (1) classified as effective, because the N-gain THB was in the high category; and (2) stated that it can be an alternative in training students' problem-solving skills, because the N-gain of problem-solving skills was in the medium category. In conclusion, the multimodel-based electronic teaching materials that were created are effective in physics learning to train students' problem-solving skills.

Keywords: Electronics, mechanical waves, multimodel, problem solving skills.

Abstrak

Bahan ajar elektronik berbasis multimodel ini merupakan salah satu inovasi pengembangan penunjang pembelajaran untuk melatihkan keterampilan pemecahan masalah. Tujuan dari penelitian ini adalah menyediakan bahan ajar elektronik berbasis multimodel yang efektif digunakan dalam pembelajaran. Model ADDIE digunakan dalam desain penelitian yang merupakan proyek dari penelitian dan pengembangan. Sebanyak 22 peserta didik kelas XI MIPA 2 menjadi subjek uji coba dari penelitian ini. Data diperoleh dari hasil belajar kognitif peserta didik. Analisis deskriptif kuantitatif digunakan untuk analisis data. Diperoleh bahan ajar elektronik, yaitu: (1) tergolong efektif, karena N-gain THB berkategori tinggi; dan (2) dinyatakan dapat menjadi alternatif dalam melatihkan keterampilan pemecahan masalah peserta didik, karena N-gain keterampilan pemecahan masalah berkategori sedang. Kesimpulannya, bahan ajar elektronik berbasis multimodel yang dibuat efektif diterapkan dalam pembelajaran fisika untuk melatihkan keterampilan pemecahan masalah peserta didik.

***Kata kunci**: Elektronik, gelombang mekanik, keterampilan pemecahan masalah, multimodel.*

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INTRODUCTION

The demands of the 21st century require students to possess a range of essential skills to thrive in an increasingly complex, technological, and interconnected world (Prijanto et al., 2024; Rachmawati et al., 2024; Wati, Maesarah, et al., 2024). These skills include critical thinking, creativity, collaboration, communication, digital literacy, and problem-solving abilities. Learning in this era should therefore emphasize active engagement, innovation, and the ability to adapt to rapid changes in technology and society (Fadlila et al., 2024; Murniati et al., 2024; Norma et al., 2024; Wati, Alfianoor, et al., 2024). In line with this, the use of digital learning media such as flipbooks can enhance interactive and student-centered learning, providing a platform for learners to explore, create, and apply knowledge effectively in the context of the Industrial Revolution 4.0. In addition, with the balance of technological developments, it is hoped that today's learning can take advantage of these developments to improve the quality of learning in order to achieve learning goals. Learning media flipbook can support learning in accordance with the era of the Industrial Revolution 4.0.

Flip PDF Professional is an interactive medium that allows the integration of various types of animated content into a flipbook. The display of Flip PDF Professional can be turned back and forth when reading, similar to the appearance of an e-book (Nurhasnah & Sari, 2020; Sriyanti et al., 2021; Susanti et al., 2020). Therefore, flipbook-based learning media are considered a smart solution for creating engaging, communicative, and interactive learning experiences that help students better understand the material being studied (Kistiono & Fitri, 2025; Marisda, Tolla, & Arsyad, 2025; Marisda, Tolla, Arsyad, et al., 2025; Syukri et al., 2024). However, in practice, based on an interview with a physics teacher at SMA Negeri 1 Alalak for grade XI, learning activities generally still rely on printed textbooks. Even during the pandemic, learning was supported only by the use of WhatsApp groups and YouTube links as supplementary media. Since October, the school has resumed face-to-face learning. Physics lessons conducted in person are focused primarily on delivering core material because the duration of each class is limited to only 45 minutes.

Not only is the flipbook-based learning medium effective for achieving learning objectives, but it also encourages students to develop the skills needed to face and overcome challenges encountered during the learning process (Fadila et al., 2025; Kharomah et al., 2024; Salamao et al., 2025). The goal of learning physics is not merely to master concepts, but also to enable students to connect different concepts and apply them in solving real-world problems. Problem-solving ability is an essential skill that must be continuously developed, as it represents one of the core competencies required in the 21st century. Problem-solving itself is a complex cognitive process that relies on fundamental thinking skills, allowing students to identify problems, analyze causes, and ultimately find appropriate solutions (Izzati et al., 2020).

The results of the preliminary study conducted on the students who participated in this trial showed that their problem-solving skills were still relatively low when applying the problem-solving stages. Most students were only able to write down the known and unknown variables without including a physical representation of the problem situation. After these initial steps, they tended to directly substitute the given information and solve the problem without first analyzing it or writing down the relevant equations. In addition, during the problem-solving process, students often omitted units and only substituted numerical values, which led many of them to skip the final stage—interpreting the results. This finding is consistent with the statement of the physics teacher at SMA Negeri 1 Alalak, who explained that students' low problem-solving ability occurs because they are accustomed to solving physics problems by merely identifying what is known, what is asked, and providing an answer, without including diagrams, analysis, or written explanations. In other words, the stages carried out by the students were not in accordance with the six-step problem-solving framework.

The solution or effort offered is that students are trained in problem-solving skills during learning, with the development of multimodel-based teaching materials. According to (Fautin et al., 2020) multimodel is a learning activity that applies more than one learning model to discuss one physics subject, with the hope of helping students achieve learning goals and making students actively construct

the knowledge obtained. Based on the results of research, after students used multimodel-based physics teaching materials, there was an improvement in learning outcomes, as indicated by post-test scores that were higher than the pre-test scores (Fautin et al., 2020). Many studies have developed multimodel-based teaching materials, which have been proven effective in achieving learning objectives and enhancing students' cognitive abilities. The mechanical wave topic was chosen because it is closely related to various phenomena in daily life and serves as a foundation for understanding subsequent physics concepts. The basic competencies in the mechanical wave topic guide students toward analytical skills, particularly problem-solving. Students in class XI MIPA 2 already possess fundamental calculation abilities and can perform simple problem-solving steps; therefore, they need learning activities that help them develop more detailed and systematic problem-solving processes. Therefore, it is necessary to develop multimodel-based physics teaching materials in a flipbook format to help students apply the steps of problem-solving in a more structured manner. For this reason, multimodel-based electronic teaching materials were developed with the aim of describing the effectiveness of the product and improving students' problem-solving skills through the use of these electronic learning materials.

METHODS

This research employed a quantitative pre-experimental design with a one-group pretest–posttest approach to determine the effectiveness of multimodel electronic teaching materials on the topic of mechanical waves in improving students' problem-solving skills. The development of the teaching materials followed the ADDIE model, which included analyzing students' needs, designing the structure and components of the flipbook, developing and validating the product, implementing it in classroom learning, and conducting an evaluation to measure its effectiveness. The study involved 22 students from class XI MIPA 2 at SMA Negeri 1 Alalak in the 2021/2022 academic year. The effectiveness of the electronic teaching materials was evaluated using a problem-solving test administered during the pre-test and post-test, supported by a problem-solving rubric to assess students' performance at each problem-solving stage. The data were analyzed using the N-gain equation (Hake, 1998) to determine improvement, and the results were interpreted according to established criteria of problem-solving skills and N-gain categories.

RESULTS AND DISCUSSION

Results of the Effectiveness of Electronic Teaching Materials

The learning outcome test is useful for measuring students' cognitive abilities which are the result of learning at school. The learning outcome test was carried out using 5 essay questions about mechanical waves for pre-test and post-test. The learning results obtained will be considered with normality and N-gain tests. The normality test aims to test the values obtained and through N-gain the effectiveness of a teaching material can be known. The results of the normality test through the Kolmogorv Smirnov test showed that the data obtained was normally distributed with a significance value of 0.679. This means that the data obtained during the pre-test and post-test can be trusted and has been tested for accuracy. Table 1 below is a summary of learning outcomes and N-gain from students.

Table 1. Descriptive statistics of learning outcomes and N-gain

Description	Pre test scores	Post test scores	*N-gain*	Category
Lowest score	0,00	53,50		
Highest score	12,50	88,00		
Average score	2,84	72,14	0,71	High
Number of students completed	0	11		
Number of students	22	22		

Based on the results summarized in Table 1, it indicates that the learning outcomes between post-

tests compared to pre-tests show a significant improvement. This improvement in learning outcomes is inseparable from the application and effect obtained by students in learning to intensively apply teaching materials. The teaching materials developed have a number of advantages, including that the teaching materials are arranged with an attractive, detailed appearance, contain a lot of explanations but are easy to understand with the use of simple terms, and the examples presented are equipped with problem-solving stages, so that students can get used to solving problems using more complete and sequential stages.

In addition, the teaching material also inserts various supports to add insight into the knowledge of students such as a glimpse of information, inventor figures, images tailored to the topic of material, learning videos and worksheet that can be opened via QR Code, material summary, and glossary (Figure 1). The developed worksheе is also equipped with questions that are tailored to learning objectives and problem solving skills, so that they can practice solving with problem solving stages through these questions. This electronic teaching material also links learning with phenomena in everyday life and problem solving skill at each meeting, so that it can make students become accustomed to solving problems using the problem solving skill stage. In research (Prastiwi, 2018) which argues that habituation and practice in learning are likely to make students able to maintain their abilities in long-term memory.

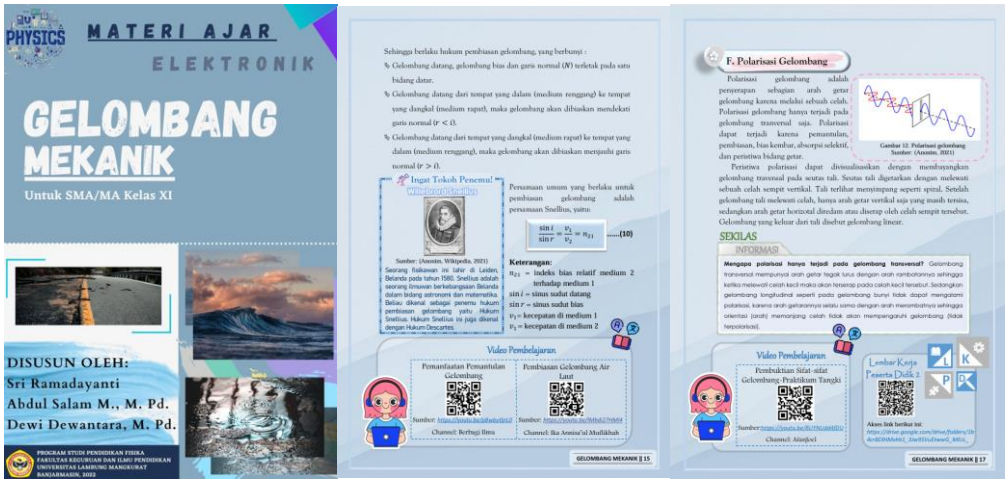

Figure 1. Display of Teaching Material

In addition to delivering the material that needs to be mastered, the learning process uses a model that can actively involve students. Learners are also trained to have social skills which include the ability to work together, share knowledge, form groups, and be responsible to group members to achieve learning goals. So that the multimodel-based learning models used are direct instruction models and cooperative teaching models. Learning is an activity through which individuals gain knowledge and experience, and the direct instruction model involves efficient problem-solving processes to improve learning outcomes (Rusmawati et al., 2023). The behavioral learning theory underlies the direct instruction model because learning depends on individuals' experiences in acquiring knowledge (Nurropidah et al., 2025). Cooperative learning is also considered one of the teaching models that enables students to achieve academic success, as its effectiveness can be observed through students' active participation in learning activities (Navisah et al., 2021; Sari et al., 2020). In addition, Vygotsky's theory serves as a foundation for the implementation of cooperative learning in the classroom, as it emphasizes the creation of a collaborative and interactive learning environment (Hananda Amelia et al., 2023). Judging from the minimum completion criteria, students who meet the minimum completion criteria at the time of the post-test more than the number of students at the time Pre-test. In addition, the results N-gain Table 1 meets the criteria for teaching materials to be effective, namely there is an increase in learning outcomes and the average N-gain is in the medium category. This increase can

indicate the effectiveness of a product, which is in accordance with the statement (Mahjatia et al., 2020) that the results of the pre-test and post-test which are different from each other can be used to determine whether a product is effective or not. Thus, the findings indicate that the multimodel-based electronic teaching materials with mechanical wave material developed in order to train problem solving skills are effective to be implemented in learning activities.

Results of Students' Problem-Solving Skills

Problem-solving skills according to it is the ability that students have to apply knowledge in order to overcome problems and be prepared to face the challenges of the 21st century, so that students have the right to be given the right and appropriate learning methods (Scott, 2023). The stages of problem-solving skills include several systematic steps. First, students begin by writing down the known information or data related to the problem. Next, they identify the unknown variables that need to be determined. After that, students proceed to analyze the problem-solving process by connecting the given information with the concepts involved. The following step is writing down the relevant equations that can be used to solve the problem. Then, students substitute the known information into the equations and perform the necessary calculations to find the solution. Finally, they interpret the results obtained to ensure that the solution is reasonable and aligns with the context of the problem. Table 2 provides a summary of the results of the average calculation of each stage of good problem-solving skills Pre-test And post-test, and the results N-gain.

Table 2. Findings from the average results of each stage of problem-solving skills and N-gain

Stages of Problem Solving Skill	Pre-test		Post-test		N-gain	Category
	Average	Category	Average	Category		
Writing down information or data	11,34	not good	75,17	good	0,59	Medium
Identifying unknown variables	21,21	less good	98,48	very good		
Analyzing problem solving	0,00	not good	64,52	good		
Writing down relevant equations	0,00	not good	54,80	good enough		
Substituting information and solving the problem	0,00	not good	57,31	good enough		
Interpretation	0,00	not good	69,69	good		

Based on the results obtained, it can be concluded that students' problem-solving skills improved at all stages after the use of multimodel-based electronic teaching materials in learning. This improvement occurred because the electronic teaching materials included sample problems with solutions that applied the stages of problem-solving, allowing students to practice these steps directly. In each learning session, students were consistently guided and trained to solve problems by following the problem-solving stages, enabling them to become more familiar with the process and more capable of applying it effectively when faced with new problems. This is also supported by research (Ramadhanti et al., 2020) that there is an increase in problem-solving scores in students because for each meeting they are always taught and trained about the stages of problem-solving skills. This statement is in accordance with the learning theory of cognitivism and constructivism where learning prioritizes the learning process and involves students in developing new ideas based on the knowledge and experience that students already have, in other words building knowledge little by little (Nurliana et al., 2021).

The increase in problem-solving skills is also shown from the calculation results N-gain problem-solving skills that show results in the medium category. Thus, based on the achievement of problem-solving skills, it indicates that this multimodel-based electronic teaching material can be an alternative to practicing problem-solving skills in learning, which means that it is in accordance with the results of the research (Astuti et al., 2020) which states that there is an increase in the results of problem-solving

skills after students in the learning process use teaching materials.

CONCLUSION

This study, which examined the effectiveness of multimodel-based electronic teaching materials on the topic of mechanical waves, revealed that based on the findings obtained, electronic teaching materials: (1) are declared effective, because the results of N-gain are categorized as high; and (2) are stated to be an alternative in practicing problem-solving skills, because the N-gain of problem-solving skills was in the medium category. In addition, the analysis conducted in this study provides empirical evidence supporting the effectiveness of multimodel-based electronic teaching materials in enhancing students' learning outcomes and problem-solving abilities. Thus, in physics learning, using multimodel-based electronic teaching materials is effectively applied to practice problem-solving skills. The practical implication of this finding is that teachers can integrate multimodel-based electronic teaching materials into classroom instruction to provide varied learning experiences, enhance students' engagement, and systematically improve their problem-solving skills.

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