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STEM MULTIMEDIA TO STIMULATE HOTS IN RENEWABLE ENERGY MATERIAL

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ABSTRACT

The rapid advancement of technology in the 21st century demands students to master Higher-Order Thinking Skills (HOTS) to face global challenges. This study aims to develop a multimedia-based STEM learning tool to stimulate HOTS in physics, particularly renewable energy topics focusing on hydro and wind energy. The research employs the ADDIE model (Analyze, Design, Develop, Implement, Evaluate) to create and test the multimedia's validity, practicality, and effectiveness. Data were collected using expert validation sheets, teacher and student questionnaires, and HOTS assessment tests. Results indicate that the multimedia is valid, practical, and effectively enhances students' HOTS. This study highlights the potential of STEM-based multimedia in providing engaging and meaningful learning experiences, particularly in abstract physics topics. These findings have implications for developing innovative learning strategies following the 2013 curriculum, emphasizing developing critical and creative thinking skills.

MULTIMEDIA STEM UNTUK MENSTIMULUSI HOTS PADA MATERI ENERGI TERBARUKAN

Kata Kunci:

Higher order thinking skills
HOTS
Multimedia interaktif
Pendekatan STEM

ABSTRAK

Kemajuan teknologi abad ke-21 menuntut siswa untuk menguasai keterampilan berpikir tingkat tinggi (HOTS) guna menghadapi tantangan global. Penelitian ini bertujuan mengembangkan multimedia pembelajaran berbasis STEM untuk menstimulus HOTS pada mata pelajaran fisika, khususnya pada topik energi terbarukan dengan fokus energi air dan angin. Penelitian ini menggunakan model pengembangan ADDIE (Analyze, Design, Develop, Implement, Evaluate) untuk menguji validitas, kepraktisan, dan efektivitas multimedia tersebut. Data diperoleh melalui lembar validasi ahli, angket guru dan siswa, serta tes HOTS. Hasil menunjukkan bahwa multimedia yang dikembangkan valid, praktis, dan efektif dalam meningkatkan HOTS siswa. Studi ini mengungkap potensi multimedia berbasis STEM dalam menciptakan pengalaman pembelajaran yang menarik dan bermakna, terutama untuk materi fisika yang bersifat abstrak.

Temuan ini berimplikasi pada pengembangan strategi pembelajaran inovatif yang sesuai dengan kurikulum 2013, dengan penekanan pada pengembangan keterampilan berpikir kritis dan kreatif.

1. INTRODUCTION

The Industrial Revolution 4.0 era changed various aspects of life, including education. This revolution is marked by the development of technologies such as the Internet of Things, artificial intelligence, robotics, nanotechnology, and data science, all of which drive the birth of new challenges in the field of education [1]. The younger generation must be equipped with 21st-century skills that include communication, collaboration, creativity, and critical thinking To face these challenges (4C) [2], [3]. These skills underlie higher-order thinking skills or higher-order thinking Skills (HOTS), which are the core of the 2013 curriculum in Indonesia. Education designed to improve HOTS is one of the keys to preparing quality human resources to face global challenges.

HOTS is a cognitive ability that involves analysis, evaluation, and creation based on Bloom's taxonomy, revised by Anderson and Krathwohl [4]. HOTS is very important in physics learning because it helps students understand abstract concepts and complex physical phenomena [5]. However, implementing learning that supports the development of HOTS is often hampered by the lack of relevant and engaging learning media. In addition, students usually feel that physics is a complex and boring subject, so they need a stimulus that can increase their interest and involvement [6], [7]. This stimulus can be learning media to integrate visual, auditory, and interactive elements.

Multimedia learning is one solution that provides a stimulus in learning [8]. Multimedia combines text, sound, video, images, animation, and simulation delivered through digital devices to convey information effectively [9]. In the context of physics learning, multimedia allows the delivery of factual and conceptual material more interestingly and interactively [10]. Interactive-based multimedia learning also helps students develop critical thinking skills through contextual learning experiences. Research shows interactive multimedia can increase student learning motivation, especially for abstract material [11].

Renewable energy is a physics topic requiring an innovative approach [12]. This material is very relevant to efforts to overcome environmental problems and energy availability in the future. Renewable energy, especially water and wind energy, has great potential to be developed in Indonesia but has not been fully taught effectively in schools [13]. Based on initial research, most teachers have not used learning media that can integrate real-world contexts with science concepts taught in class. In fact, multimedia based on the STEM (Science, Technology, Engineering, Mathematics) approach can potentially bridge this gap.

The STEM approach is an integrated learning approach that connects science, technology, engineering or creativity, and mathematics with real-world applications [14], [15]. This approach encourages students to think critically and creatively through project-based activities (PjBL) [16]. In physics learning, the STEM approach allows students to understand the concept of renewable energy through experiments and simulations designed to improve their analytical, evaluative, and creative skills [17].

However, although the STEM approach has been widely recognized, its implementation in interactive multimedia that supports HOTS is still minimal. Previous research shows that teachers often use conventional methods that are less effective in motivating students to think critically and creatively [18]. This is a major challenge in developing learning media relevant to student needs and the curriculum. The use of technology, such as STEM-based multimedia, can be a solution to create a more interesting and meaningful learning experience for students.

Previous research has examined the use of STEM-based multimedia, including the development of STEM-based multimedia to improve creative thinking skills [19], to improve science learning outcomes [20], the development of digital multimedia for anatomy and physiology materials [20], and STEM-based multimedia design to stimulate HOTS [21]. These studies provide a strong basis for the idea that STEM-based multimedia has great potential to improve various aspects of student skills, especially in problem-solving, analysis, and creativity.

This study was conducted to continue the research conducted by [21], which designed a STEM-based multimedia design to stimulate HOTS on the topic of water and wind energy. The study focused on the Analyze and Design stages of the ADDIE model and produced a valid multimedia design according to the assessment of physics experts. However, the study has not continued with the multimedia development, implementation, and evaluation stages. Therefore, this study aims to continue the development of the design into a valid, practical, and effective multimedia product to stimulate HOTS on water and wind energy materials. In addition to strengthening previous research, this study also provides new contributions by integrating visual, auditory, and kinesthetic elements to create a more holistic and meaningful learning experience.

2. METHOD

This study used the Research and Development (R&D) method with the ADDIE (Analyze, Design, Develop, Implement, Evaluate) development model [22]. This model was chosen because it provides a systematic framework for producing valid, practical, and effective STEM-based interactive multimedia in stimulating students' higher-order thinking Skills (HOTS) [23]. ADDIE consists of five integrated stages: needs analysis, design, development, implementation, and product evaluation [24]. This study focuses on developing STEM-based multimedia for water and wind energy materials as power plants, following the needs of the 2013 curriculum. This development process includes media design based on visual, auditory, and kinesthetic components to increase student involvement in physics learning [25]. This model also allows for revisions at each stage so that the resulting product meets learning quality standards. After receiving ethics approval, the research was conducted.

The population in this study were all grade XII students at SMA Negeri 9 Bandar Lampung. The sample consisted of one experimental class, class XII IPA 2, which was selected using a purposive sampling technique. This class was selected based on the availability of multimedia support facilities and students' learning needs. After receiving consent from parents and students, the research was conducted. In addition to students, this study also involved five expert validators, consisting of three physics lecturers with a master's degree and two experienced physics teachers. The validators were tasked with evaluating the content and construction of the multimedia to ensure its suitability with the learning objectives and HOTS indicators [26]. The validation process was carried out in stages, from expert testing to one-on-one testing with five students to ensure the multimedia was easy to understand.

The research instruments included a validation questionnaire, student response questionnaire, and pretest-posttest test [27]. The validation questionnaire was used to assess the feasibility of the product based on aspects of content, design, and practicality of multimedia [28]. The validators provided an assessment on a Likert scale of 1–4, covering indicators of the suitability of the material with core and basic competencies, as well as the feasibility of animation, simulation, and interactive questions [29]. The student response questionnaire was used to measure the practicality of multimedia, such as readability, attractiveness, and ease of use. The pretest and posttest tests comprised 10 essay questions to measure students' HOTS in analysis, evaluation, and creation. The validity of the questions was tested using product moment correlation, while reliability was calculated using Cronbach's Alpha formula to ensure consistency of measurement results [30].

The research procedure included five ADDIE stages that lasted for four months. The Analyze stage began with a needs analysis through a questionnaire to 32 physics teachers and 43 students to determine students' difficulties in understanding physics material, the approach used by teachers, and the availability of learning facilities. The Design stage involved creating a storyboard, syllabus, and STEM-based lesson plan, which included water and wind energy material, learning videos, interactive animations, and quizzes equipped with feedback. In the Development stage, the multimedia design was realized into a product ready to be tested, validated by experts and tested for readability through one-on-one tests with five students. The Implementation stage included a field trial with a quasi-experimental one-group pretest-posttest design, where multimedia was applied in learning to measure its effectiveness in stimulating students' HOTS. The last stage, evaluation, was carried out to analyze multimedia's validation results, practicality, and effectiveness. Figure 1 shows the flowchart of this study.

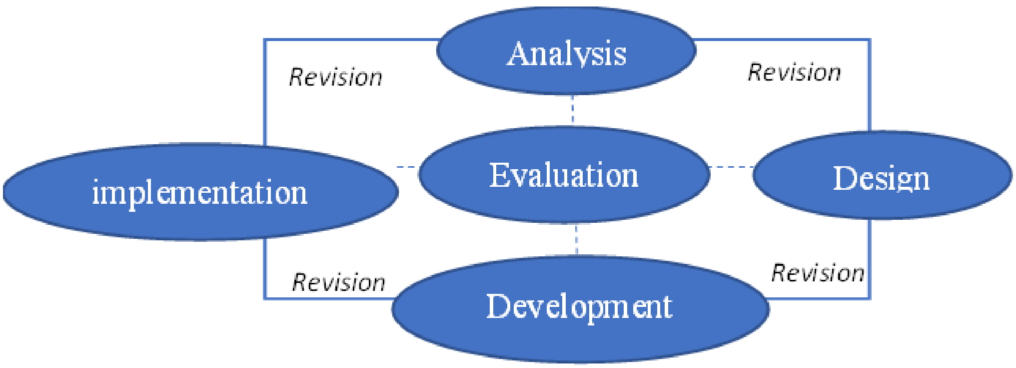

Figure 1. Research Flowchart

The data obtained were analyzed quantitatively using various analysis techniques. The validity of multimedia was calculated based on the average score of the validator on the validation questionnaire. The practicality of multimedia was measured through the percentage of student responses to the questionnaire, which included readability, attractiveness, and ease of use indicators. The effectiveness of multimedia was evaluated by comparing the pretest and posttest results using the paired sample t-test to determine the significance of the increase in students' HOTS. In addition, the effect size value was calculated to measure the impact of multimedia on improving students' abilities. Prerequisite tests such as the Kolmogorov-Smirnov normality and homogeneity tests were carried out to ensure that the data met statistical assumptions. N-gain analysis was also used to assess the improvement in students' skills based on the low, medium, or high effectiveness classification.

3. RESULTS AND DISCUSSION

This research continues previous research conducted by Diansah [21]. Previous research focused on the analysis and design stages, which resulted in a STEM-based multimedia design to stimulate students' HOTS on water and wind energy materials. Ten physics teachers considered the design valid based on the criteria of the connection between the material and the STEM components and the potential of multimedia in stimulating high-level thinking skills. However, the study has not continued the product development, implementation, and evaluation stages.

This study continues the Development stage to realize the validated design plan. At the development stage in the ADDIE model, the conceptual framework of STEM-based multimedia is realized in prototype 1, which is ready to be tested for feasibility. This multimedia product was developed to facilitate students' understanding of water and wind energy material as a power plant by containing three main components: chapter opener, learning activities, and evaluation.

The chapter opener contains the front cover, basic competencies, learning indicators, and learning objectives. This cover design used Canva and integrated into Microsoft Sway as the main platform. The cover visualization contains attractive illustrations in the form of material titles, images of water and wind energy, and developer information. The standard display of content, such as basic competencies, indicators, and learning objectives, is shown in detail from Figure 2 to Figure 5.

Figure 2. Example of a Multimedia Cover Display with a STEM Approach

Figure 3. Example of Basic Competency Display

Figure 4. Example of Learning Indicator Display

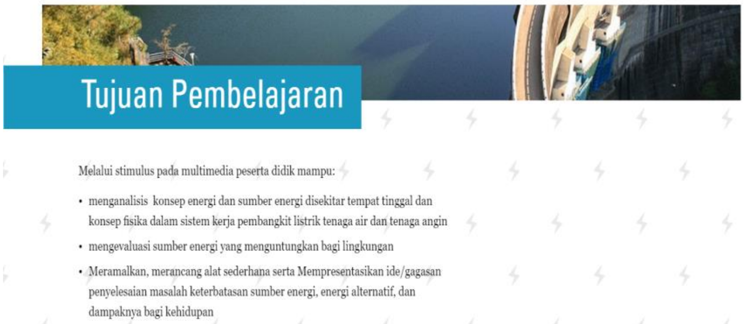

Figure 5. Example of Learning Objectives display

The learning activities in this multimedia are divided into three main topics designed to provide a deeper understanding of renewable energy. Topic 1 discusses the concept of energy and energy sources that are the basis for students' understanding of the forms and types of energy used in everyday life. Topic 2 focuses on wind energy as a power plant by presenting how wind kinetic energy can be converted into turbine technology. Meanwhile, Topic 3 discusses water energy as a power plant that illustrates the use of water flow to generate energy through a hydroelectric power plant (PLTA) working system. Each topic in this multimedia is presented through a combination of text, video illustrations, animations, and simulations designed to visualize abstract concepts more realistically and interactively. This presentation aims to provide a more interesting, in-depth learning experience and support the STEM approach, especially in Science, Technology, Engineering, and Mathematics. The multimedia display on each topic can be seen in Figures 6 and 8.

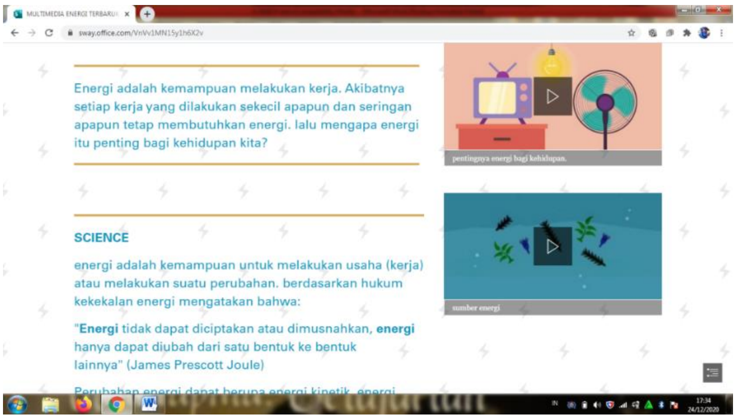

Figure 6. Example of STEM-based Multimedia Display on Topic 1

Figure 7. Example of STEM-based Multimedia Display on Topic 2

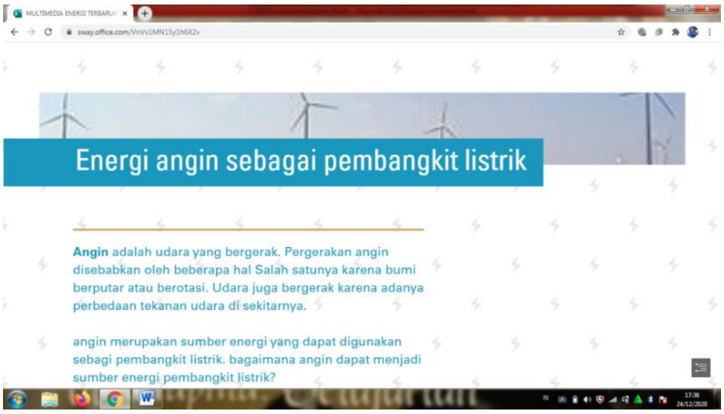

Figure 8. Example of STEM-based Multimedia Display on Topic 3

The evaluation section in this multimedia contains multiple-choice questions equipped with interactive feedback for each selected answer. The evaluation questions consist of five questions designed to measure students' understanding of the material that has been studied. The evaluation display can be seen in Figure 9.

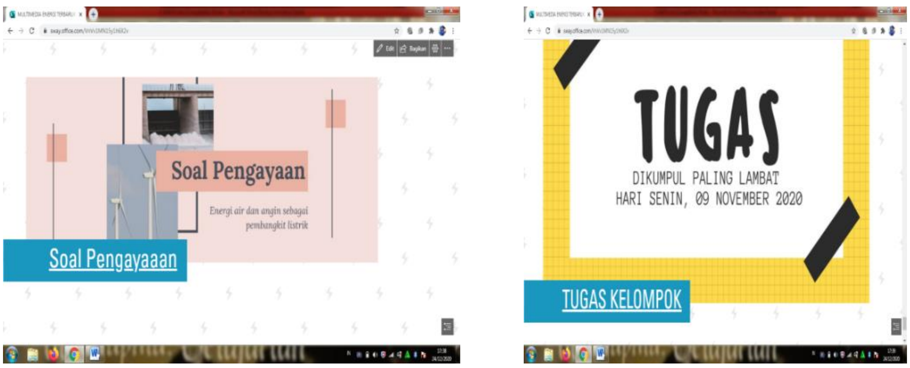

Figure 9. Example of Enrichment Questions and Assignments

Next, the product validation test stage was carried out to assess the feasibility of the STEM-based multimedia developed before being implemented in learning. This validation test involved three content experts and two construct experts competent in physics education and learning technology. The assessment was carried out using a Likert-scale validation sheet with a score range of 1–4, which covered several main aspects, namely the suitability of the material, design construct, and connectivity with the STEM approach. The validation test results showed that STEM-based multimedia obtained a high average score in each aspect. The results of this validation test are shown in Table 1, which shows the average score of each aspect of the assessment by the validator. The validator also provided several inputs to improve the multimedia, such as simplifying the language in the text material, improving the quality of animation in the wind energy simulation, and adding examples of renewable energy applications in everyday life. These inputs were realized during the revision of the multimedia product to ensure better quality before the implementation stage.

Table 1. Expert Validation Test Assessment Results

No	Validator	Type of Test	Score	Qualitative Statement
1	Expert Lecturer 1	Content Validity	4,4	Very Good
		Construct Validity	4,2	Very Good
2	Expert Lecturer 2	Content Validity	4,0	Good
		Construct Validity	3,9	Good

3	Expert Lecturer 3	Content Validity	3,8	Good
		Construct Validity	3,8	Good
4	Expert Practitioner 2	Content Validity	4,3	Very Good
		Construct Validity	4,3	Very Good
5	Expert Practitioner 3	Content Validity	4,3	Very Good
		Construct Validity	4,3	Very Good

Based on Table 1. validation of STEM-based multimedia products showed positive results with an average content validity score of 4.16 (83.2%) and construction validity of 4.1 (82%). Both of these scores are in the "Very Good" category, indicating that the product is suitable for use as a learning medium. Content validity confirms that the material in the multimedia is following basic competencies, learning indicators, and objectives that have been set. In addition, this multimedia effectively presents material through text, images, animations, and video illustrations that support student understanding. Construction validity emphasizes the quality of display design, navigation, and feature integration in multimedia. The validator provides suggestions for improvements such as; simplifying language, increasing color and font consistency, and adding sources to the videos or images used. These suggestions have been implemented to improve the product before further testing.

Furthermore, a one-on-one test was carried out to test the product's readability and ease of operation. The readability aspect shows that the text and language used in the multimedia are in accordance with the level of student understanding. The systematic material structure and supporting illustrations help students understand the concept of water and wind energy more easily. Meanwhile, in terms of ease of use, multimedia navigation is considered intuitive and features such as video, animation, and simulation are easily accessible without any obstacles. Overall, these results indicate that STEM-based multimedia is feasible to use in physics learning to help students understand the concept of renewable energy interactively and interestingly. Overall, the expert validation test results indicate that STEM-based multimedia products have very good quality and are feasible to use in physics learning. High content and construction validity indicate that this product has met pedagogical and technical standards in supporting improving understanding of physics concepts through the STEM approach.

The implementation phase was conducted to test the practicality and effectiveness of using STEM-based multimedia on water and wind energy as a power plant. The field trial was conducted on 30 class XII MI3 SMA 9 Bandar Lampung students during two online meetings via Zoom and WhatsApp Group. In the first meeting, the learning process began with a pretest to determine the initial abilities of students. After that, students were directed to access STEM-based multimedia through the link that had been shared. Core learning includes reflection and research, where students explore text, animation, video, and simulations contained in the multimedia. The material studied includes the concept of energy and energy sources and the working mechanisms of water and wind energy as power plants. The first session was closed with a reflection to record students' initial impressions and understanding. In the second meeting, students were divided into four groups to carry out project-based learning through the research, discovery, application, and communication phases. This activity requires students to analyze the energy potential in their area and design solutions in simple hydropower plant designs. Learning ends with implementing a posttest and final reflection to evaluate understanding and achievement of high-level thinking skills (HOTS). The implementation results show that STEM-based multimedia is considered practical and effective in improving students' understanding of renewable energy material. The multimedia-based learning process allows students to actively participate in solving real problems through the exploration of science, technology, engineering, and mathematics (STEM) concepts. The effectiveness test was conducted to determine the improvement in student learning outcomes after using STEM-based multimedia on water and wind energy material as a power plant. The effectiveness measurement was carried out by comparing the pretest and posttest values in the experimental class and through analysis of normality tests, N-gain, and effect size. The normality test using the Kolmogorov-Smirnov test showed that the pretest and posttest data were normally distributed with significance values of 0,102 and 0.183 (> 0,05), respectively. This indicates that the data meets the assumptions of a normal distribution. The results of the N-gain analysis showed an average value of 0,67 with moderate criteria, indicating an increase in students' high-level thinking skills (HOTS) after using STEM-based multimedia. This analysis shows that the developed multimedia is effective in facilitating students to understand and analyze the material being taught.

Furthermore, the paired sample t-test was used to test the hypothesis of a significant difference between the pretest and posttest scores. The analysis showed a p-value = 0,000 (<0,05), meaning a significant difference between the scores. The average pretest score was 50,27, while the average posttest score increased significantly to 83,34. The results of the effect size calculation using Cohen's d formula produced a value of 0,47, which is included in the moderate category. This value shows that the use of STEM-based multimedia has a fairly strong influence on improving students' HOTS. Table 2. Shows a recapitulation of the results of the HOTS indicator assessment of the experimental class.

Table 2. Recapitulation of the results of the HOTS indicator assessment for the experimental class

No	Indicator HOTS	Question Number	Average Value per Question Item		Average	
			Pretest	Posttest	Pretest	Posttest
1	Analysis	1	41,67	59	53,88	75,5
		5	80,83333	100		
		6	39,16	67,5		
2	Evaluation	2	55	100	47,5	91,25
		4	40	82,5		
3	Creating	3	45	95	45	95
	Average		50,27	83,33		

The evaluation results show that STEM-based multimedia effectively improves students' high-level thinking skills, especially in analyzing, evaluating, and creating. This success is supported by the integration of visual, auditory, and simulation elements that help students understand abstract concepts through a science, technology, engineering, and mathematics (STEM) approach.

The results of this study indicate that the STEM-based multimedia developed successfully improved students' high-level thinking skills (HOTS), especially in analyzing, evaluating, and creating. The improvement of HOTS skills is supported by interactive elements in multimedia, such as animation, simulation, and video, which help students visualize the abstract concepts of water and wind energy. These results are in line with Mayer's Dual Coding Theory [31], which states that the combination of information processing through visual and auditory channels can improve students' understanding and retention. In addition, the STEM approach in multimedia allows students to apply science concepts, use technology, and understand technical and mathematical procedures in real contexts. This study aligns with Diansah's study [21], which states that STEM-based multimedia can potentially improve students' HOTS through an approach based on science, technology, engineering, and mathematics. In addition, this study supports the findings that simulations and animations in physics multimedia can help visualize abstract concepts, making it easier for students to understand. However, the increase in HOTS in the analyzing indicator in this study was lower than other indicators. This contrasts the study [32], which stated that the STEM approach tends to be more effective in improving analytical skills. This difference may be due to limitations in the learning duration and the material's characteristics that require deeper exploration. This study has several important implications for the development of physics learning. First, using STEM-based multimedia effectively improves students' higher-order thinking Skills (HOTS), especially in water and wind energy materials. This shows that integrating elements of science, technology, engineering, and mathematics in one multimedia product can facilitate understanding complex and abstract concepts through an interactive approach. Second, the results of this study can be a reference for teachers in designing innovative learning that combines technology and the STEM approach to encourage students to think critically and creatively. Third, the successful implementation of this multimedia supports efforts to improve the quality of physics learning in the era of the Industrial Revolution 4.0, where technology is one of the main demands in education.

Although the study results show the effectiveness of STEM-based multimedia, several limitations must be considered. First, this study only involved 30 students in one experimental class, so the results obtained cannot be generalized to a wider population. Second, the relatively short learning duration, only two meetings, limited in-depth exploration of each HOTS indicator, especially in analytical skills, which tended to increase lower than other indicators. Third, the implementation of multimedia was carried out in online learning, so limited internet access and devices owned by students became technical obstacles that affected the effectiveness of multimedia implementation.

This needs to be considered in further research to obtain more optimal results. Based on the study results and the limitations found, several suggestions for further research exist. First, similar research should be conducted with a larger sample size and longer learning duration to make the results more comprehensive and generalizable. Second, the development of STEM-based multimedia needs to be equipped with additional interactive features, such as virtual labs or educational games, which can increase student engagement and maximize HOTS improvements. Third, multimedia implementation should be carried out in face-to-face (offline) learning to overcome technical obstacles that often arise in online learning, such as limited internet access. Thus, the effectiveness of STEM-based multimedia can be tested in more ideal learning situations and support improving the quality of physics education.

4. CONCLUSION

This study shows that STEM-based multimedia effectively improves students' high-level thinking skills (HOTS) in renewable energy material, especially in analyzing, evaluating, and creating. The effectiveness test results through the pretest and posttest showed a significant increase, with an average value of 50.27 in the pretest and 83,34 in the posttest, with an N-gain value of 0,67 (moderate category). These results are reinforced by the paired sample t-test, which shows a p-value = 0,000 (<0,05), which means that STEM-based multimedia can significantly improve students' HOTS. Interactive elements in multimedia, such as animation, simulation, and video, have been shown to help students visualize the abstract concepts of water and wind energy, making them easier to understand. This product is feasible as an innovative physics learning media supporting the STEM approach. However, this study has limitations in the number of samples and relatively short learning duration. These findings contribute to developing innovative learning strategies following the 2013 curriculum, emphasizing developing critical and creative thinking skills.

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