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The Impact of STEM-based Interactive Multimedia on Vibrations and Waves to Improve Students' Critical Thinking Skills and Learning Independence

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Abstract

Indonesia implements the Merdeka Curriculum, which focuses on cultivating Pancasila education. The dimensions of the Pancasila student profile consist of critical and independent thinking, which are also found in the 21st-century skills, and STEM-based learning may be one of the solutions to improving the two dimensions. This research aims to unveil the impact of applying STEM-based interactive multimedia on vibrations and waves, particularly in improving students' critical thinking skills and learning independence. The method was experimental research with a nonequivalent group pretest-posttest design, in which the experimental class used STEM-based interactive multimedia while the control class used PowerPoints. Experts validated the multimedia and instrument before the implementation, and the effectivity was measured using the t-test. The results revealed that the multimedia effect on critical thinking skills scored 5.6763 t-count > 2.0025 t-table, while the impact on learning independence was 7.3462 t-count > 2.0025 t-table. The outcomes show significant differences between the experimental and control classes; therefore, we conclude that STEM-based interactive multimedia is effective in improving critical thinking skills and learning independence.

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INTRODUCTION

Indonesia currently applies the Merdeka Curriculum, which emphasizes the development of Pancasila values. The Pancasila student profile comprises six values: faith and devotion to the Almighty God, global diversity, independence, mutual cooperation, critical thinking, and creativity (Nurhayati et al., 2022). Critical thinking is not only related to the personality of Indonesian students, but it is also one of the skills that students in the 21st-century should acquire and improve by getting used to learning. According to Mu'minah and Aripin (2019), STEM-based learning can improve 21st-century skills, including critical thinking, creative thinking, communication, and collaboration.

Critical thinking is one of students' abilities in the 21st-century. Ramdani et al. (2020) stated that critical thinking is the ability of a person's thought process to evaluate or consider the evidence, assumptions, and logic underlying the ideas of others. This statement is supported by Facione (2015), who described critical thinking as self-regulation entailing analyzing and synthesizing information to make reasoned judgments or decisions. Further, a study by Rosmalinda et al. (2021) explained that students scored low in answering PISA-type questions. Therefore, it is necessary to increase critical thinking skills in addition to teaching them. The ability to think critically builds independent thinking to carry out innovations useful in students' practical lives and later in the working world (Beniche et al., 2021).

On the other hand, the independence of learning is a process for students to manage self-regulated learning for their time, place, and resources (Aulia et al., 2019). Moreover, Maylisa et al. (2022) stated that independent learning aims to liberate education through free thinking and innovation. The importance of learning independence is to help students master the learning objectives with their own abilities so that they can achieve the best results (Arista et al., 2022). With independent learning, students research and ask questions rather than relying solely on their teacher or instructor's materials. They also take ownership of their educational path by setting goals and monitoring their progress. (Arisinta et al., 2019).

Studies on how STEM affects the improvement of 21st-century skills, including critical thinking and learning independence, have been widely undergone. Roudlo (2020) argued that STEM projects are linked to everyday-life problem-solving, stimulating students' critical thinking while learning independently. Besides, Sartika (2019) stated that STEM encourages students' attitudes, knowledge, and skills and improves students' critical thinking abilities in forming logical thinking while experiencing direct learning from the surrounding environment. Surely, STEM needs exemplary tools to achieve learning objectives, and multimedia is a good resource.

Multimedia learning occurs when a learner builds a mental representation from words and pictures that have been presented. According to Li et al. (2019), multimedia learning facilitates students in collaborative activities, learning control, generative images, and advanced principles in education. The multimedia learning principles focus on the maximalisation of the text-and-illustrations effect, the spatial contiguity effect with text-and-illustration, and the personalization effect with animation-and-naration (Mamase, 2019; Railean, 2015). Many experts have researched STEM-based multimedia. For instance, Prayitno & Hidayati (2023) and Syawaludin et al. (2019) who concluded that STEM-based learning positively impacts critical thinking skills and fosters independence of learning.

The use of STEM-based multimedia in Physics was examined by Yulianti et al. (2022), who applied scratch-assisted media to momentum and impulse topics. The study revealed that scratch-assisted media enhanced students' 21st-century skills up to the medium category and successfully attracted students' attention. However, this program is not available as an application. Another research by Pramuji et al. (2020) developed STEM-based interactive multimedia on environmental pollution materials. It obtained favorable student responses; nevertheless, it has some shortcomings, including the absence of student worksheets and the larger scale test. For these reasons, the researchers are eager to disclose the impact of STEM-based multimedia on critical thinking skills and learning independence.

METHODS

This is an experimental research with a nonequivalent pretest-posttest group design. The experimental class used interactive multimedia, while the control class used PowerPoints.

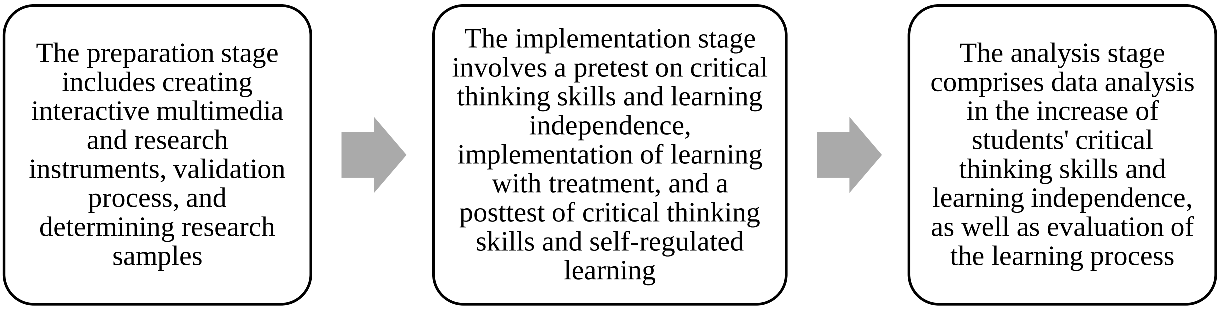


Table1. Research Procedure Scheme

The research subject was the eighth grade of MTs Mathalibul Huda Mlonggo with a cluster random sampling technique with the same strata sample. The homogeneity test was carried out using the F test, resulting in grade 8F as the experimental class and 8G as the control class. The dependent variables are critical thinking skills and learning independence. According to Ennis (2011), indicators of critical thinking skills include (1) introductory explanation (providing simple explanations), (2) essential support (building fundamental skills), (3) inferences (conclusion), (4) high-level explanation (regulations and detailed explanation), (5) strategy and tactics (strategy and tactics). On the other hand, indicators of learning independence, according to Hidayati & Listyani (2013), include (1) having a sense of responsibility, (2) having self-confidence, (3) behaving based on one's initiative, (4) not being dependent on other people, (5) exercising self-control, and (6) having a disciplined manner. The instruments were test and non-test, where the first was in the form of a reasoned multiple choice test to measure students' critical thinking abilities, and the latter used questionnaires to test the validity of content and media experts, learning independence, the practicality of the multimedia, and student responses to learning.

In the implementation stage, the students had a pretest and posttest regarding their critical thinking skills and learning independence. The normality of the pretest and posttest data for critical thinking skills were measured using the Chi-Kuadrat formula. The pretest results in the experimental class were 10,26 X^2count < 11,07 X^2table, while the control class obtained 10,89 X^2count < 11,07 X^2tabel. Thus, it concluded that the pretest data were normally distributed. As for the posttest results, the experimental class scored 8,78 X^2count < 11,07 X^2table, while the control class got 10,83 X^2count < 11,07 X^2table. The results inferred that the posttest data were normally distributed.

The increase in critical thinking abilities and learning independence was examined using the N-gain test. In contrast, the significant differences between the experimental and control classes were computed using the t-test. Also, the practicality of interactive multimedia was assessed using the Likert-scale questionnaires.

Figure 1. The home display menu contains a title, materials, a user guide, and an organizer

Figure 2. The materials section consists of vibrations and waves and an explanation of STEM content.

Figure 3. The content section includes learning outcomes, objectives, introduction, LKPD, simulation, materials, and reflection.

Figure 4. The LKPD menu section provides answers directly in the columns

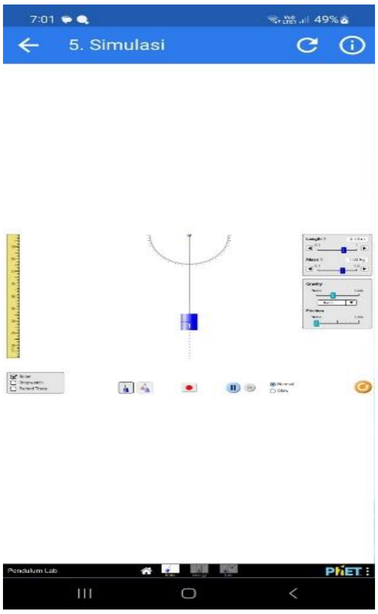


Figure 5. Online practicum is available in the simulation section to obtain the investigation data.

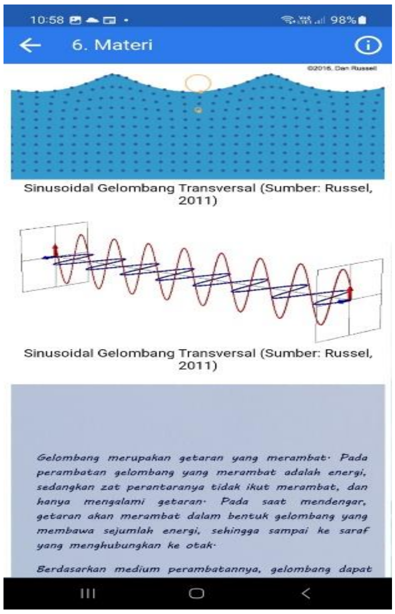


Figure 6. The content displays animations of the movement of different waves.

RESULTS AND DISCUSSION

The average pretest score on critical thinking skills was 44 for the experimental and 42 for the control class. The average posttest score on critical thinking skills was 71 for the experimental class and 56 for the control class. The N-gain test found that the average increase in the experimental class' critical thinking skills was 0.47 for the "medium" category and 0.22 for the control class, categorized as "low." Different uses of teaching media influenced these results. Pramuji et al. (2020) stated that STEM learning in collaboration with technology provided meaningful learning for students.

According to Ennis (2011), each indicator for the N-gain test on critical thinking skills had 5 aspects, with 10 indicators. All of the indicators are seen in Figure 7.

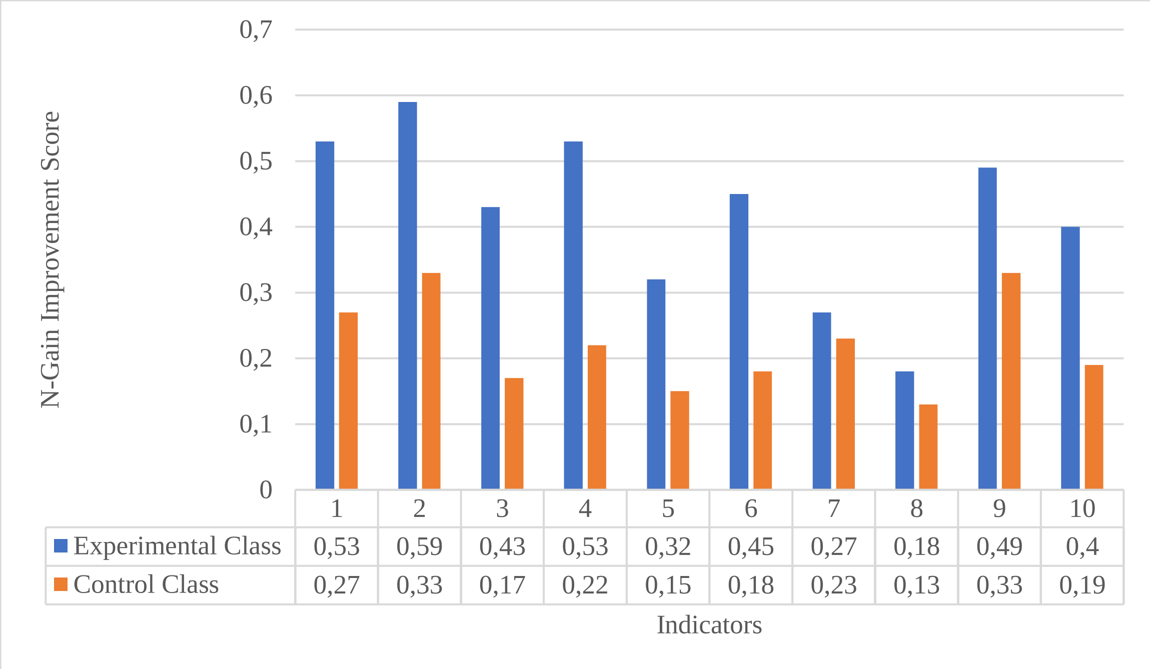


Figure 7. Differences in N-Gain Test Results for Each Indicator of Critical Thinking Skills in the Experimental and Control Class

Indicators:
(1) focused questions
(2) discussion analysis
(3) asking questions and responding to questions or clarifications
(4) accuracy of sources
(5) observing and examining the observation reports
(6) drawing and considering the induction results
(7) reasoning to derive and consider results
(8) defining terms
(9) identifying assumptions
(10) determining measures

The first indicator intends to train students to focus on the materials taught, thus answering the right choice despite similar distractive options. Then, students were given problems based on daily cases or events related to vibrations and waves to measure students' analysis of specific topics. The deeper the topic analysis, the better the results will be. After having a discussion, they were allowed to have a question-and-answer session. The student's curiosity is seen in the proposed questions, where their comprehension of the topic is reflected through the answers. Despite the thorough understanding of the materials, answering questions needs a wide range of sources to support the arguments being delivered. Hence, source accuracy and credibility are two of many things to be considered. Upon the Q&A session is over, students are asked to arrange reports. There are no firm requirements for what is included in a report. Every school, company, laboratory, task manager, and teacher may have a distinguished format, depending on the needs. However, generally, a report shall involve an analysis of existing data and literature, problem-solving, and solutions (Hayati et al., 2019; Sa'adah et al., 2020). That being said, indicators 5 to 10 are presented in the student report.

Proper use of technology by involving sensory organs helps students link new information to prior knowledge and understand relationships between concepts (Widyawati, 2021). The N-gain test results for each indicator in Figure 7 show that the improvement obtained in the experimental class was higher than in the control class, indicating that the

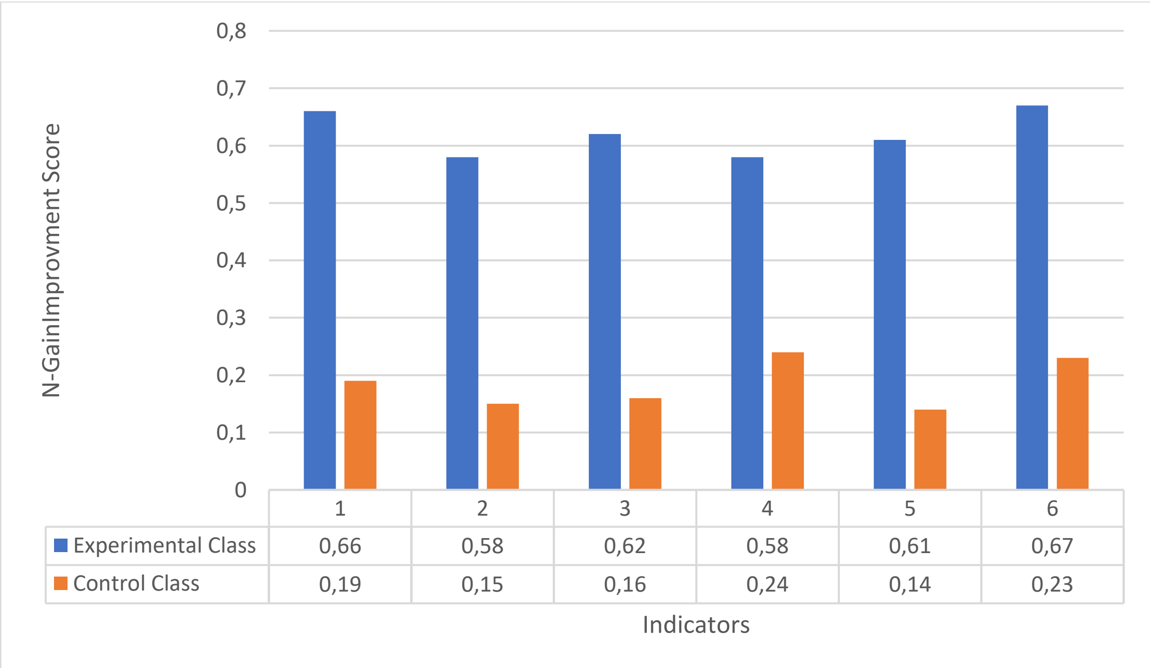
STEM-based interactive multimedia on vibrations and waves can increase critical thinking skills higher than PowerPoints. The hypothesis test obtained 5.6763 t_{count} > 2,0025 t_{table}, meaning that Ha is accepted since the experimental class showed a significant difference in developing critical thinking skills.

The use of STEM-based interactive multimedia has effectively enhanced critical thinking skills. This aligns with Supriyadi et al. (2023) proving that STEM-blended learning effectively increases students' scientific literacy. Moreover, Seage & Türegün (2020) stated that STEM learning provides meaningful experiences for students and could be combined with methods or media to attract participants' attention to generate effective learning. This favorable outcome can be achieved through the habituation of both teachers and students.

The changing role of education has reinforced the integration of multimedia technology, leading to a new paradigm in education. Multimedia offers unique advantages in education and also enables us to provide a way by which learners can experience their subject vicariously. The key to achieving this experience is providing simultaneous images, video, and audio rather than in a sequential manner. According to Syawaludin et al. (2019) and Wahyuningsih et al. (2022), new experiences led by multimedia have stimulated students' liveliness to seek information, process and analyze data, argue and solve problems. Hence, multimedia could boost their independence and, at the same time, improve critical thinking skills.

The average pretest score on learning independence was 49.58 for the experimental class and 52.90 for the control class, both of which were in the “low” category. On the contrary, the experimental class’ average posttest scored 81.01 in the “high" category, and the control class scored 61.88 in the “medium” category. The N-gain test resulted in 0.60 for the experimental class in the "medium" category and 0.19 for the control class in the "low" category. These results prove that proper stimulus triggers curiosity, which then leads to independence in learning Arifin et al. (2021); in other words, multimedia is an appropriate enticement for students.

There are six indicators of learning independence measured using the N-gain. Figure 8 shows the differences in learning independence between the experimental and control class.



	1	2	3	4	5	6
Experimental Class	0,66	0,58	0,62	0,58	0,61	0,67
Control Class	0,19	0,15	0,16	0,24	0,14	0,23

Figure 8. Differences in N-gain Test Results for Each Aspect of Learning Independence in the Experimental Class and Control Class

Indicators:
(1) responsibility
(2) self-confidence
(3) initiative
(4) independence from others
(5) self-control
(6) discipline

The experimental class obtained the “high” category on indicator 1,3,5,6 and the “medium” category on indicator 2 and 4. Meanwhile, all aspects of the control class received “low” category. The hypothesis testing obtained 7,3462 t_{count} > 2,0025 t_{table}; thus, the Ha was accepted. The results showed that using interactive multimedia on vibrations and waves could improve students' learning independence and make them more motivated, effortless, responsible, and able to learn (Hamandia, 2020; Khairani et al., 2023). This study’s results add to the many other similar studies on multimedia. For instance, Asyhari & Sa’adah (2022) who unveiled that multimedia hinders students from being passive as they do not only sit and listen to lectures but actively seek relevant information beneficial for their study. Further, research by Saputra & Alexon (2023) developed an Android-based interactive multimedia and successfully motivated students for self-regulatory learning. Similarly, Asmar & Delyana (2020) also proved a close connection between learning independence and critical thinking skills. The latter acts as a cognitive strategy for the self-regulation process in learning. Self-regulation can develop independent learning, requiring students to think critically in forming new ideas. After learning in the experimental class, the students' responses reached 82.51% in the "good" category, while the control class scored 72.24% in the "good" category. Based on these results, the experimental class students respond better to learning than students in the control class.

CONCLUSION

The STEM-based interactive multimedia significantly improves critical thinking skills and learning independence; the two are closely related and thus enhanced simultaneously. The multimedia has been declared valid and practical for classroom usage. Future research should advance the application by adding supporting features like a chat room between student-teacher and student-student. Moreover, this study contributes as a reference for teachers who want to apply multimedia in their classes and for future researchers who are about to conduct similar studies.

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