



Comparison of student learning outcomes using artificial intelligence and physics textbooks on harmonic vibration material

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Abstract

Technological advances in the digital era have brought significant changes in the world of education, including in physics learning methods. This study aims to analyze the learning outcomes of students who use Artificial Intelligence (AI) and physics textbooks on harmonic vibration material. The study used a quantitative method with a quasi-experimental design of the control group pretest-posttest type. The study population was all students of class XI FA in one of the high schools in Serang Regency. The sample consisted of two classes selected purposively, namely XI FA 1 as the experimental class and XI FA 2 as the control class, each with 34 students. The instrument was in the form of 15 multiple-choice questions based on Bloom's Taxonomy (C1–C4) which had been tested for validity, reliability, difficulty level, and distinguishing power. The experimental class received AI-based learning, while the control class used a physics textbook. The results of statistical tests using SPSS 30.0 showed significant differences between the two classes with a significance value of $0.038 < 0.05$. The average posttest score of the experimental class was 82.72 (very high category), while the control class was 76.64 (high category). This shows that AI-based learning is more effective in helping to understand physics concepts, especially complex concepts such as harmonic vibrations. However, textbooks still have an important role in building conceptual understanding. Therefore, AI should be used as a complement, not a substitute for textbooks, to optimize student learning outcomes in physics learning.

Keyword: artificial intelligence; physics textbook; learning outcomes; physics learning; harmonic vibrations

Abstrak. Kemajuan teknologi di era digital telah membawa perubahan signifikan dalam dunia pendidikan, termasuk dalam metode pembelajaran fisika. Penelitian ini bertujuan menganalisis perbandingan hasil belajar siswa yang menggunakan Artificial Intelligence (AI) dan buku teks fisika pada materi getaran harmonik. Penelitian menggunakan metode kuantitatif dengan desain quasi-eksperimental tipe control group pretest-posttest. Populasi penelitian adalah seluruh siswa kelas XI FA di salah satu SMA di Kabupaten Serang. Sampel terdiri dari dua kelas yang dipilih secara purposive, yaitu XI FA 1 sebagai kelas eksperimen dan XI FA 2 sebagai kelas kontrol, masing-masing 34 siswa. Instrumen berupa 15 soal pilihan ganda berdasarkan Taksonomi Bloom (C1–C4) yang telah diuji validitas, reliabilitas, tingkat kesukaran, dan daya pembeda. Kelas eksperimen mendapatkan pembelajaran berbasis AI, sedangkan kelas kontrol menggunakan buku teks fisika. Hasil uji statistik menggunakan SPSS 30.0 menunjukkan perbedaan signifikan antara kedua kelas dengan nilai signifikansi $0,038 < 0,05$. Rata-rata nilai posttest kelas eksperimen adalah 82,72 (kategori sangat tinggi), sedangkan kelas kontrol 76,64 (kategori tinggi). Hal ini menunjukkan bahwa pembelajaran berbasis AI lebih efektif dalam membantu pemahaman konsep fisika, terutama konsep kompleks seperti getaran harmonik. Meskipun demikian, buku teks tetap memiliki peran penting dalam membangun pemahaman konseptual. Oleh karena itu, AI sebaiknya digunakan sebagai pelengkap, bukan pengganti buku teks, untuk mengoptimalkan hasil belajar siswa dalam pembelajaran fisika.

INTRODUCTION

Education is an essential process in developing individual potential to face future challenges. As a means of creating quality human resources, education plays an important role in determining the direction of civilization (Nurkholis, 2013; Arifudin et al., 2024; Pazah et al., 2024; Siregar et al., 2024). This is reflected in the national education goals, namely to produce a generation that is religious, moral, knowledgeable, skilled, physically and mentally healthy, and responsible. One of the keys to achieving this goal is the development of an education curriculum that is relevant to the dynamics of the times (Nurhuda, 2022; Anis Aprianti et al., 2023; Marzuqi et al., 2023).

The Independent Curriculum is here as a response to these needs, emphasizing contextual, enjoyable learning and encouraging independent learning (Ainur Rofiah et al., 2023; Yuniar et al., 2023). However, implementation in the field is still far from ideal. Limited teacher understanding, lack of teaching media, and minimal infrastructure are the main obstacles (Marwiyah et al., 2024; Yanti et al., 2024; Mustabil et al., 2025; Naibaho et al., 2025). This has an impact on declining student learning achievement, especially in elementary and secondary schools.

In physics learning, the lecture method still dominates (Purnamasari et al., 2020), which causes a lack of student participation and impacts learning outcomes (Putri et al., 2019). Based on the results of a questionnaire conducted by Nurul (2022), As many as 88% of students learn through lectures, and only 22% get practical experience. In fact, 53% of students want more practical work and 34% discussions. Difficulty understanding physics concepts, inappropriate use of media, and memorization and mathematical materials are the main causes of low student learning outcomes. Low learning outcomes in physics learning are also caused by students having difficulty understanding physics concepts, the media chosen is not appropriate, and physics material is difficult to understand because it is memorized and contains mathematical elements (Neizhela et al., 2015; Sa'diyah et al., 2021; Safitri et al., 2022; Amalisholeh et al., 2023; Widiarini et al., 2025). One of the difficult materials is simple harmonic vibrations with a completion rate of only 34.28 (Sugara et al., 2016; Amalia et al., 2018; Wijaya et al., 2020; Feziyasti et al., 2024). Based on research by Ni'mah et al., (2017) in one high school, it was shown that student learning outcomes on this material were relatively low, with only 12.44%–34.7% of questions being answered correctly.

The development of digital technology has also encouraged the adoption of Artificial Intelligence (AI) in education (Afif, 2019; Mambu et al., 2023; Habsy et al., 2024; Hasnida et al., 2024). AI can support 21st century skills, such as critical thinking and problem solving (G. E. Putri et al., 2019; Anas et al., 2024; Fitrianti et al., 2024; Putriani et al., 2021), and enables the integration of technology in physics learning (Fauziah et al., 2022; Mahardika et al., 2023; Azizah et al., 2024; Perdana et al., 2024). One application of AI is ChatGPT, which provides personal interaction and helps students understand the material.

In addition to AI, physics textbooks have long been a primary source of learning. Textbooks offer a systematic structure in explaining the theories, concepts, and laws of physics, which helps students build a basic understanding before developing higher-order thinking skills (Hartono et al., 2013; Lolita et al., 2021; Sittariandani et al., 2022; Anshari et al., 2024). However, textbooks are static and cannot provide direct interactive feedback to students. However, reading textbooks can still train students to absorb information independently, as well as hone critical thinking skills in understanding and connecting physics concepts (Fadilla et al., 2023; Apriyanti et al., 2024; Rahma et al., 2024; Effendi et al., 2025).

Along with these challenges, it is important to evaluate the effectiveness of learning using AI compared to physics textbooks in the context of harmonic vibration material. This study aims to compare the learning outcomes of students who use ChatGPT-based AI with students who use physics textbooks in learning this material. The focus of this study is to measure the extent to which these two methods affect students' understanding and cognitive skills in the domains of remembering (C1), understanding (C2), applying (C3), and analyzing (C4) according to Bloom's taxonomy (Andreson et al., 2001).

Thus, this study is expected to provide deeper insights into the comparative effectiveness between AI-based learning and physics textbooks in helping students understand complex physics concepts, as well as contributing to the development of more innovative and effective learning methods in the digital era.

RESEARCH METHODS

The research used a quantitative method with a quasi-experimental design type control group pretest-posttest design. The research was conducted in one of the high schools in Serang Regency in February 2025. The population in this study were all FA XI grade students in one of the high schools in the Serang Regency area. The sample consisted of two classes selected using purposive sampling technique, namely XI FA 1 as the experimental class and XI FA 2 as the control class, each totaling 34 students.

The study began with giving a pretest to determine the initial condition and ensure that there was no significant difference in mastery of the material before the treatment was given. Furthermore, the experimental class received learning using AI based on ChatGPT, while the control class used physics textbooks. The instrument was in the form of 15 multiple-choice questions based on Bloom's Taxonomy (C1-C4) that had been tested for validity, reliability, difficulty level, and distinguishing power. This test was given during the pretest and posttest. Data were analyzed using prerequisite tests (normality and homogeneity) and continued with an independent t-test and normalized gain (N-Gain) test using SPSS version 30.0. to determine whether there were significant differences in learning outcomes between the experimental and control classes.

RESULTS AND DISCUSSION

Based on the research that has been conducted, the results show that there are differences in students' cognitive learning outcomes in the experimental class using artificial intelligence-based learning with the control class using physics textbooks.

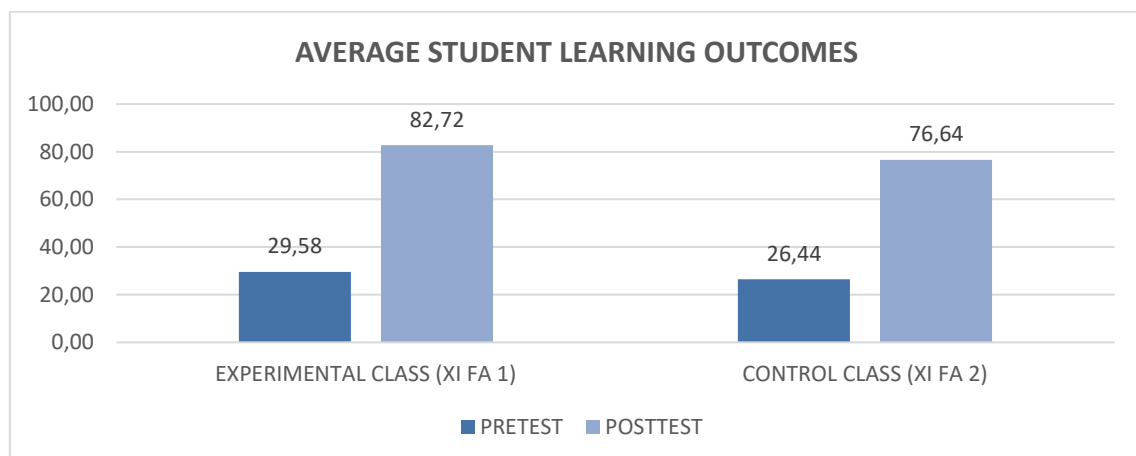


Figure 1 Average student learning outcomes

Table 1 Statistical Test of Student Learning Outcomes

Statistical Test	Experiment Class (XI FA 1)	Control Class (XI FA 2)	Information
Normality	<i>Pretest</i> 0,099	<i>Pretest</i> 0,063	Normally Distributed Data
	<i>Posttest</i> 0,200	<i>Posttest</i> 0,184	
Homogeneity	0,976		Homogeneous Data
Independent t-test	0,038 < 0,05		H_0 is rejected and H_1 is accepted

Based on Figure 1. The overall average value, the pretest results of the experimental class obtained an average value of 29.58 and the control class obtained an average value of 26.44, meaning that both have not yet reached the KKM (85). This indicates that both classes have equivalent cognitive abilities before being given different treatments. After being given different learning treatments, the posttest results showed a significant increase. The experimental class obtained an average value of 82.72, while the control

class obtained an average of 76.64. This difference shows that artificial intelligence-based learning has a greater impact on improving student understanding compared to learning using physics textbooks.

Then, based on Table 1, the results of the normality test showed that the pretest and posttest data in the experimental class (XI FA 1) and the control class (XI FA 2) had a significance value greater than 0.05. The significance value in the experimental class was 0.099 for the pretest and 0.200 for the posttest, while in the control class it was 0.063 and 0.184, respectively. Thus, it can be concluded that the data is normally distributed and meets the requirements for parametric testing. Furthermore, the homogeneity test conducted on the posttest data produced a significance value of 0.976 (> 0.05), which indicates that both data groups come from a homogeneous population. The results of the independent sample t-test showed that the significance value was 0.038 (< 0.05), so the null hypothesis (H_0) was rejected and the alternative hypothesis (H_1) was accepted. In other words, there is a statistically significant difference between the learning outcomes of students who use AI-based learning media and students who use physics textbooks on harmonic vibration material.

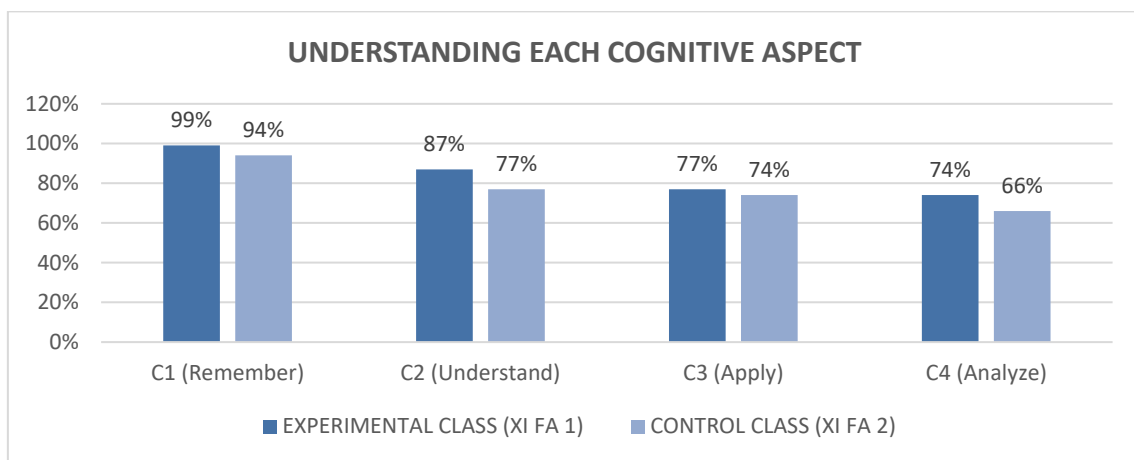


Figure 2 Results of data on understanding each cognitive aspect

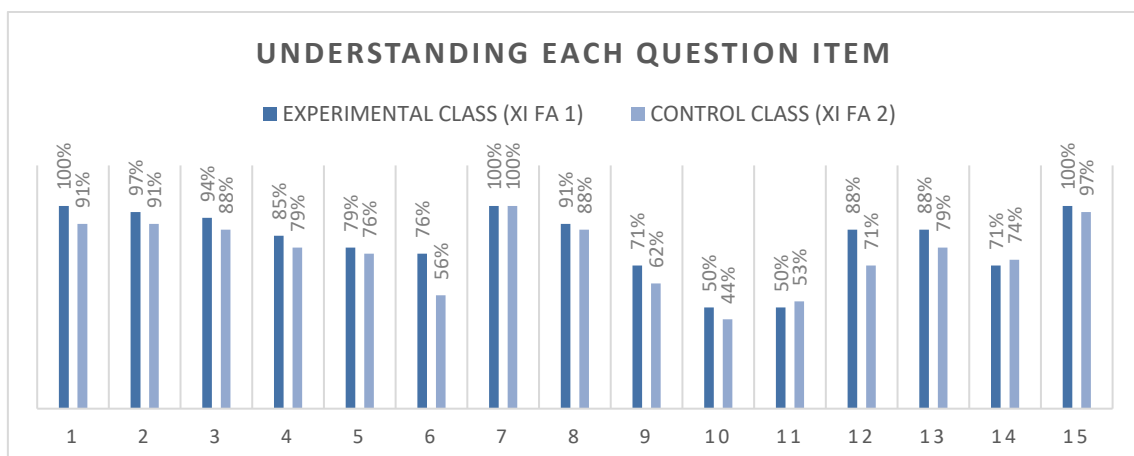


Figure 3 Results of data on understanding each question item

Based on Figure 2, there is a significant difference in the average cognitive ability at each level. Level C1 (remembering) in the experimental class (XI FA 1) has the highest average value of 99% with a very good category compared to levels C2, C3, and C4. This is because at the cognitive level C1 it is related to students' ability in memorizing and recalling the knowledge they have received (Sudjana, 2011).

Based on Figure 3, in the experimental class (XI FA 1), the lowest score was obtained on question number 11 (C4) with an average of 83%. This question tests the ability to analyze the relationship between potential energy and kinetic energy in harmonic motion. The high level of difficulty at the C4 level makes

some students have difficulty in arranging the logic of the relationship between concepts, even though it has been supported by AI-based learning. The highest score, which is 100%, was obtained on questions 1, 7, and 15. Questions 1 and 7 are included in the C1 level which asks for the definition and examples of harmonic vibrations, while question number 15 is at the C3 level which asks for the calculation of spring constants. This success shows that students find it easier to answer basic and applicable questions that have been learned through visualization and interaction during learning.

On the other hand, the control class (XI FA 2) obtained the highest score on question number 7 (C1) with an average of 100%, and the lowest score on question number 10 (C3) with an average of 70%. Question number 10 requires the application of the swing frequency formula, but many students have difficulty because the form of the question is different from the examples in the textbook and the lack of similar practice questions.

The posttest results showed that students in the experimental class (XI FA 1) who participated in Artificial Intelligence-based learning (ChatGPT) obtained a higher average score compared to the control class (XI FA 2) who used a physics textbook. The high average score achieved showed that students in the experimental class were able to remember important information, understand basic concepts, apply formulas in the context of questions, and analyze the relationship between physics variables better after participating in AI-based learning.

This finding is in line with the research results of Gontina et al. (2023) and Widodo et al. (2024) which stated that Artificial Intelligence-based learning significantly improves student learning outcomes through a visual, interactive, and contextual approach. AI-based learning has also been shown to be able to overcome the limitations of conventional approaches such as the use of textbooks that are one-way and provide less space for exploration.

Further analysis of the test items showed that the highest achievement of students in the experimental class was in indicator C1 (remembering), while the lowest achievement was in indicator C4 (analyzing), especially in question number 11 which requires an understanding of the relationship between potential energy and kinetic energy. The complexity of the questions and the need for high-level reasoning are challenges in themselves. This complements the findings of Fatmawati et al. (2024) who emphasized that the effectiveness of AI is highly dependent on the active involvement of students in exploring AI features independently. This means that even though AI provides in-depth visualizations and explanations, not all students are able to draw logical conclusions if they are not yet accustomed to reflective and exploratory learning.

On the other hand, in question number 10 which is at level C3 (applying), students in the control class had difficulty when they had to use the formula to calculate the frequency of pendulum swings because the form of the question did not match the example in the book. This indicates that the textbook-based approach is still limited in supporting students' flexibility of thinking. This finding is reinforced by Hidayat et al. (2024) who stated that textbooks tend to present material in a linear and less contextual manner, making it difficult for students when faced with a variety of questions.

Learning with AI also increases students' active participation during the learning process. They do not only receive materials passively, but also actively ask questions and compare answers with explanations from AI, as reflected in student interactions with ChatGPT that have been guided through LKPD. AI provides explanations according to the context and level of student understanding, and is able to respond to questions directly, as expressed by Kholis et al. (2025) who emphasized that AI helps students build understanding independently through a more flexible learning process.

The involvement of AI also supports the formation of learning motivation and students' self-confidence in solving physics problems, as reinforced by Amir et al. (2024) who reported that the integration of AI in Advance Organizer-based learning was able to significantly increase students' mastery of physics concepts.

Thus, the results of this study strengthen and complement various previous findings on the advantages of AI in learning. The novelty of this study lies in the focus of evaluation based on specifically measured cognitive indicators (C1–C4), as well as the implementation of the use of ChatGPT at the high school level on harmonic vibration material. These findings indicate that AI not only has an impact on improving learning outcomes in general, but also has a different influence on each cognitive level, with the

highest effectiveness on the ability to remember and apply, and its own challenges on the ability to analyze in depth.

CONCLUSION

This study shows that the use of Artificial Intelligence (AI)-based learning media is significantly more effective than the use of physics textbooks in improving student learning outcomes in the Harmonic Vibration material. This is shown through the results of statistical tests with a significance level of 0.038 (<0.05), which indicates a significant difference between the two learning groups. The average learning outcomes of students in the experimental class using AI reached 82.72 with a very high category, while the control class using physics textbooks obtained an average of 76.64 with a high category. This difference in results reflects the superiority of AI media in providing a more interactive, visual, and adaptive learning experience, as well as its ability to provide direct feedback that supports students' understanding of abstract physics concepts. Artificial Intelligence (AI)-based learning media can be used as a strategic alternative in improving student learning outcomes, especially in abstract physics materials such as harmonic vibrations. To support the effectiveness of its implementation, further research is recommended to conduct a preliminary study to ensure student readiness, educator competence, and adequate infrastructure support. However, this study has several limitations. First, the implementation of AI-based learning is still highly dependent on the availability of adequate internet access and digital devices. Second, the characteristics of students and teachers as technology users are not studied in depth, even though this factor can influence the success of using AI in learning. Third, this study only focuses on the cognitive aspect, so it does not cover the influence of AI on learning motivation, creativity, or critical thinking skills as a whole. As a recommendation, further research is advised to consider the readiness of technology in schools, the digital competence of educators and students, and expand the focus of the study on the affective aspect and high-level thinking skills so that the use of AI in learning is more optimal and comprehensive.

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