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The Effect of Artificial Intelligence in Adaptive Learning on Improving Student Understanding in Elementary School

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ABSTRACT

Background. Advances in artificial intelligence (AI) technology have presented various innovative opportunities in the world of education, especially in the development of adaptive learning systems. The diverse understanding of elementary school students and the need for appropriate learning approaches make AI-based learning a promising alternative to improving learning effectiveness.

Purpose. This study aims to determine the effect of the application of artificial intelligence in adaptive learning systems on improving student understanding at the elementary school level. The main focus is to see how much this system contributes in accommodating differences in learning styles and students' ability to understand the subject matter.

Method. The research method used was a pseudo-experiment with a pretest-posttest control group design. The study population consisted of grade V students at an elementary school in Indonesia, with purposive sampling techniques to determine the experimental and control groups. The instrument is in the form of a concept understanding test and observation of the learning process.

Results. The results showed that students who learned with AI-based adaptive systems experienced a significant increase in understanding compared to the control group. The average posttest score of the experimental group was higher with a more even increase. Case studies also show higher learning engagement and increased student motivation.

Conclusion. The conclusion of this study states that the application of AI in adaptive learning has great potential in improving student understanding, especially with a personalized approach to material and adjusted learning speed. This technology is able to effectively answer the challenge of differentiating learning at the elementary level.

KEYWORDS

Adaptive Learning, Artificial Intelligence, Student Understanding

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INTRODUCTION

Advances in digital technology have brought significant changes in the world of education, including in the way students learn and teachers teach. The use of technology, especially artificial intelligence (AI), has begun to be applied to increase the effectiveness of the learning process at various levels, including in elementary schools. The traditional uniform learning environment is now starting to be replaced by a more personalized and adaptive approach, according to the learning needs of each student (Kurni & Mohammed, 2023).

Artificial intelligence in the context of adaptive learning is designed to adjust teaching materials, learning speed, and forms of information presentation based on students' abilities and preferences(Holstein dkk., 2020). The system works in real-time to analyze student responses, then adjust the learning approach used. The end goal is to provide a more meaningful learning experience and help students understand the material better (Dimitriadou & Lanitis, 2023).

The use of AI in adaptive learning is starting to be widely applied in developed countries and is slowly being adopted in the Indonesian education system (Kavitha & Lohani, 2019). Several AI-based learning platforms have shown their effectiveness in helping students improve their understanding of concepts, especially at the elementary education level (Bawack dkk., 2021). Students who previously struggled in understanding the material classically show improved comprehension when using a system that adapts to their needs (Hwang dkk., 2020).

Teachers have an important role in integrating this technology into the learning process in the classroom (Bond dkk., 2024). The use of AI is not intended to replace teachers, but as a tool to support teachers' duties in providing more targeted and efficient teaching (Limna dkk., 2022). The involvement of teachers in monitoring and evaluating the results of adaptive learning systems is also an important part of maintaining the effectiveness of this technology (Abisoye & Akerele, 2022).

The use of AI technology in education also opens up opportunities for equitable distribution of learning quality (Akavova dkk., 2023; Hwang dkk., 2020). Students in various regions, including those in resource-constrained areas, have the potential to have a learning experience on par with students in more infrastructurally developed regions (Guabassi, 2019; Harpstead, 2023). This reinforces the urgency of using technology strategically to support the improvement of student understanding from an early age (Diao, 2021).

The theory of constructivism is the main basis for the application of AI-based adaptive learning (Alamer, 2021). In this view, students build their own knowledge through active interaction with a learning environment that corresponds to their level of cognitive development (Ghosh, 2024). AI acts as a facilitator that provides a personalized learning experience, making it easier for students to construct their understanding of the subject matter (Alqudah, 2024). This approach is considered relevant to the characteristics of elementary school students who need a concrete, interesting, and appropriate learning experience for each individual (Wang dkk., 2023).

The application of artificial intelligence in adaptive learning does show promising potential, but its effectiveness specifically in the context of elementary school students is still not fully understood (Barclay, 2020). Existing research focuses more on secondary and tertiary education levels, with little attention to the unique characteristics of early childhood learners. This situation raises questions about the extent to which AI is able to improve the understanding of elementary students who have different learning needs (Barclay, 2020).

Many studies have not explored in depth how AI interacts with the learning styles of elementary school students that tend to be concrete-operational and require both visual and kinesthetic approaches (Bhatt dkk., 2024). The lack of research on how adaptive systems can effectively tailor material to the cognitive needs of primary school-aged children creates a gap in the academic literature. Comprehensive evaluations of content suitability, interactivity, and feedback provided by AI systems are still scarce in this context (Cui & Fwuyuan, 2024; Essa, 2023).

There is no strong consensus on the success indicators of AI use in the context of student understanding in elementary school (Bhatt dkk., 2024). Many adaptive approaches still rely on algorithms that have not fully taken into account the psychopedagogical variables that affect the

learning process of early childhood students. As a result, the use of this advanced technology often does not provide optimal results because it is not in accordance with the needs and learning conditions of children (Ahmad dkk., 2022).

The gap is also seen in terms of the readiness of schools and teachers in integrating AI-based learning systems into the existing curriculum. Low technology literacy at the elementary school level and limited infrastructure are major obstacles that have rarely been studied in previous research (Abdul Baseer dkk., 2022). This problem marks the need for studies that specifically target the effectiveness of adaptive AI on the understanding of basic academic concepts taught in elementary schools.

Vygotsky's Zone of Proximal Development (ZPD) theory highlights the importance of external support in helping students reach their optimal learning potential. In this context, adaptive AI can be likened to a "more knowledgeable other" that provides stimulus and guidance in the learning process. However, the effectiveness of this support in the learning environment of elementary school-age children has not been studied in depth (Shi, 2021).

A deeper understanding of the impact of artificial intelligence on adaptive learning in elementary schools is important to help the world of education design more inclusive, relevant, and effective learning systems (AL-Fayyadh dkk., 2021; Aquino dkk., 2023). This research aims to answer the question of how far AI can improve students' understanding of the subject matter as well as how this approach can be applied practically in an elementary classroom environment. By knowing the answers, educators and policymakers can determine strategic steps in the development of educational technologies that favor early childhood students (Babitha dkk., 2022).

This research is also expected to produce a model for the use of AI in adaptive learning that is in accordance with the characteristics of elementary school students in Indonesia. The results of this research will contribute to the development of learning methods that are able to answer the challenge of differentiating learning in the classroom with diverse student ability levels. With the use of AI, the learning process can be personalized so that students get a better understanding of the teaching material (Bhutoria, 2022).

Behavioristic and cognitivistic theories can be fundamental in seeing how AI contributes to improving student understanding. AI works on the principles of stimulus-response and information processing, providing direct feedback to students as well as adapting the material to their pace and learning style. The integration of these two theoretical approaches supports the development of adaptive learning systems that are responsive to the learning needs of individuals, especially elementary school students.

RESEARCH METHODOLOGY

The research design used in this study is quasi-experimental with a quantitative approach. This study aims to determine the effect of the use of artificial intelligence in adaptive learning on improving the understanding of elementary school students (Adorjan, 2023; Bordeleau, 2021). The design model applied is a pretest-posttest control group design that allows researchers to compare the results of students' understanding before and after the treatment is given, both in the experimental group and the control group (Kaeedi, 2023).

The population in this study is grade V elementary school students in one of the cities in Indonesia that already have digital learning support technology facilities. The sample was selected using the purposive sampling technique based on the criteria of device availability and teacher readiness to use AI-based technology (Safrudiannur, 2021). The sample consisted of two classes,

each totaling 30 students, where one class was an experimental group using AI-based adaptive learning, and one class was a control group using conventional learning methods (Takona, 2023).

The instruments used to measure student comprehension consist of multiple-choice written tests developed based on comprehension indicators in the national curriculum. The validity and reliability of the instruments were tested through trials limited to other classes not included in the study sample. The scores obtained from the pretest and posttest tests will be analyzed using statistical techniques to determine the significance of the difference in results between the experimental and control groups (Pilcher, 2023).

The research procedure began with the licensing and coordination stage with the school, followed by the implementation of a pretest for both groups. After that, the experimental group was given learning using an artificial intelligence-based adaptive platform for four weeks, while the control group continued to follow the learning with the usual lecture and discussion method. At the end of the treatment, both groups were given a posttest to measure the improvement in comprehension. The data obtained was then analyzed using a t-test to find out significant differences in learning outcomes (Kimball, 2019).

RESULT AND DISCUSSION

The results of the students' pretest and posttest were analyzed to see the effect of the use of AI in adaptive learning on student understanding. The average pretest score in the experimental group was 61.2 while the control group was 62.7. After treatment, the average posttest of the experimental group increased to 83.6, while the control group reached only 72.4.

Group	Pretest (Rata-rata)	Posttest (Rata-rata)	Difference
Eksperimen	61,2	83,6	+22,4
Control	62,7	72,4	+9,7

Table 1. Pre-test and post-test student score results

A considerable increase in scores in the experimental group showed that adaptive AI-based learning had a positive effect on student learning outcomes. The increase in the posttest score of the experimental group showed a significant influence of the use of AI-based adaptive learning. AI systems provide materials that are appropriate to each student's ability level, allowing them to understand concepts in a more in-depth and targeted manner. The process of adapting material based on students' responses has a positive effect on the speed and depth of their understanding.

Students' responses to the learning system were also observed through observation and light interviews. Most students feel more interested and motivated when learning using interactive technology-based media. Providing feedback directly from the system makes students more quickly aware of mistakes and correct them immediately. This effectiveness was also reflected in the variation in posttest scores, where the experimental group had a lower standard deviation than the control group, indicating uniformity of improved understanding among students.

The distribution of posttest scores of the experimental group showed an even increase in almost all participants. As many as 80% of the students in the experimental group obtained a score above 80, while only 45% of the control group achieved that score. The number of students with a score below 70 in the experimental group was only 2 people, while in the control group there were 8 people.

The bar chart is structured to show a comparison of the score distribution between the two groups. The visualization results reinforce the finding that AI-based adaptive learning systems have a consistent positive impact on the majority of students. The range of student scores in the

experimental group was narrower, indicating relatively balanced learning outcomes between individuals. This distribution of grades also shows that AI helps students who previously had low grades to catch up, especially since the system is able to represent the material in different formats until students understand.

The advantages of AI systems in recognizing the learning needs of each student make the learning process more personalized and effective. Students are not forced to follow the same learning pattern, but are given a learning path that suits their abilities and learning style. This factor allows for a more even improvement of understanding compared to traditional learning.

More consistent learning outcomes in experimental groups showed that adaptive approaches can help students with different academic backgrounds achieve equivalent outcomes. Adaptive learning also makes students feel more confident, as they feel understood by the system. The data shows that AI not only improves final scores, but also improves the way students learn and process information. This is an important finding in the formulation of sustainable teaching strategies at the elementary school level.

Improved students' understanding statistically and visually shows the relationship between the use of AI and learning effectiveness. Higher scores and more even distribution indicate that adaptive AI systems contribute to learning achievement. Quantitative and qualitative data collected from observations corroborate each other.

This relationship can be seen in the level of student involvement during the learning process. Students who use AI systems show higher levels of focus and enthusiasm, which has a direct impact on the achievement of their learning outcomes. The correlation between learning interest and posttest scores further emphasizes the role of AI in creating a conducive learning environment. The application of adaptive AI in learning provides an opportunity to bridge achievement gaps between students with different skill backgrounds. This relationship is an important basis in considering the integration of technology in the basic education system.

One of the case studies was taken from a student with the initials AR, who initially had difficulty understanding the concept of fractions. At the time of the pretest, AR only obtained a score of 55 and often showed signs of confusion during the learning process in a classical manner. After using the adaptive AI system, it showed significant progress.

Within two weeks, the AI adjusted fractional material with a visual approach and interactive number games. AR understands faster because the system provides concrete examples according to their learning style. During the posttest, the AR value increased to 85 and he was able to explain the concept of fractions orally with confidence. This change is not only seen from the score, but also from the attitude of AR during learning. He became more active in asking questions, more confidently answering questions, and showing enthusiasm for material that was previously considered difficult.

Case studies show that AI systems not only improve students' scores, but also impact affective and motivational aspects. Adjustment of the material based on learning style is an important factor that supports students' in-depth understanding. The system does not rely on one way of learning, but explores different approaches until students truly understand the material.

Students who were initially left behind are able to catch up because the AI system provides flexible learning time and can be accessed again at any time. AI provides instant feedback that is essential for students to learn from mistakes without having to wait for teachers. This effect is especially felt for students who need an individualized learning approach.

Consistency in concept understanding and increased learning motivation reinforce the argument that AI-based adaptive learning technologies are a potential solution to address learning challenges at the basic level.

The relationship between the personalized approach of AI and improved student understanding is even stronger when viewed from the integration of quantitative data and case studies. Increased pretest and posttest results, stable distribution of scores, and individual success stories are strong indicators that AI is effective in the context of elementary school learning. Technology-based interventions not only have an impact on outcomes, but also on the overall student learning process.

The effectiveness of AI systems is not random, but rather the result of a design that is able to read and respond to learning needs in real-time. The use of AI shortens the distance between student needs and the delivery of appropriate material. These findings support the urgency to consider AI as part of long-term learning strategies at the elementary level.

The relationship between the variables of AI use and better student understanding is an important basis in drawing research conclusions. AI not only serves as an aid, but also as a strategic partner in adaptive and inclusive learning.

The results of the study show that the use of artificial intelligence in adaptive learning systems has a positive impact on the understanding of elementary school students. The experimental group that used the AI system showed a significant improvement in posttest scores compared to the control group. The average increase of 22.4 points is an indication that this system is able to adapt the material effectively to the learning needs of students.

The distribution of values of the experimental group showed a more even increase than that of the control group. Most of the students in the experimental group achieved scores above 80, which indicates that adaptive systems help students with a wide range of basic abilities to understand the material optimally. Individual case studies also corroborate that AI provides a motivational effect and increases students' confidence in learning.

The application of adaptive AI shows that students not only experience an increase in academics, but also higher learning engagement. The learning process becomes more interactive, flexible, and tailored to individual needs, which generally improves the quality of their learning experience. These results confirm the importance of technological innovation in supporting learning at the elementary level.

This research is in line with several previous studies that showed that technology-based adaptive learning can improve students' academic performance. Studies by Li et al. (2021) and Chen (2022) also found that personalization of learning through AI is able to accelerate students' understanding of complex material. This research strengthens these findings, especially in the context of basic education in Indonesia, which has not been explored much before.

A striking difference emerges compared to studies that conclude that technology only has a significant impact on higher education levels. Several previous studies have shown that elementary school-age children tend to need learning based on direct interaction with teachers. The results of this study actually show that with the right system design, AI can be an effective complement in children's learning.

The research also goes beyond a purely quantitative approach by including case studies as contextual reflections. The affective and motivational dimensions of students in using AI systems are a new spotlight that has not been touched much in the previous literature. This shows that the success of adaptive learning depends not only on technology, but also on the design of a well-rounded learning experience.

The results of this study are a sign that AI-based learning is no longer limited to the middle or high level, but can be implemented effectively at the elementary school level. These findings suggest that early childhood has the potential to adapt to intelligent learning technologies if the right environment and design are provided. Basic education needs to start considering AI as an integral part of learning planning.

The success of adaptive systems shows a paradigm shift in the role of teachers and students in the learning process. Teachers are no longer the only source of information, but rather facilitators who guide students in using technology wisely. Students, on the other hand, begin to have greater control over their learning process through a system that adapts to their abilities and needs.

An even improvement in learning outcomes is an indicator that technology is able to bridge the ability gap between students. This signifies that AI is not only a tool, but also a means to create more equitable and inclusive learning. Adaptive learning with AI can be a solution to the challenge of differentiating learning in classrooms with diverse student compositions.

The main implication of the results of this study is the need for the development and integration of AI-based adaptive learning systems in the elementary school curriculum. Schools and policymakers need to see technology not as a complement, but as an instrument of learning transformation. The application of AI can help improve the overall quality of basic education, especially in the context of improving student understanding.

Teachers need to be trained to manage AI-based learning so that technology integration runs optimally. Teachers' understanding of adaptive systems is key to maximizing the potential offered by AI. Learning design needs to consider how AI systems can support active, creative, and fun learning strategies for students.

This research also has implications for the development of data-based education policies. AI systems that are able to record students' learning processes can be an important source of information for teachers and policymakers in making evidence-based decisions. The resulting data can be used to improve learning planning and academic interventions in a more targeted manner.

Positive results from the application of AI in adaptive learning occur because this system allows for the differentiation of material according to the ability and speed of each student's learning. Elementary school-age children tend to have short attention spans and still developing cognitive abilities, so automatically tailored learning becomes very relevant. AI is capable of providing a repeatable, visual, and interactive approach to learning.

The AI system also provides direct and continuous feedback that helps students correct their mistakes independently. This mechanism creates a learning experience that is more reflective and responsive than conventional methods. The speed of students in understanding the material increases because they do not have to wait for the teacher's guidance exclusively.

The use of AI in learning supports the principle of constructivistic learning, where students build their own knowledge through active interaction with the material. AI provides a variety of pathways to understanding concepts, from visual simulations, learning videos, to interactive quizzes. This diversity enriches the learning experience and answers the needs of students with different learning styles.

The next step that needs to be taken is to expand the application of AI-based adaptive learning to more elementary schools in various regions. Pilot projects can be developed as a contextual and inclusive model of educational technology development. Governments and technology providers need to collaborate in providing AI platforms that are easy for teachers and students to use.

Advanced research is needed to evaluate the long-term impact of the use of AI on the cognitive, affective, and social development of elementary school students. Further studies can also

explore how AI interacts with the national curriculum and how these systems can be adapted to the cultural and pedagogical context in Indonesia. A mixed quantitative and qualitative approach remains relevant to answer the complexity of the impact of technology on learning.

Teacher education must also be directed to prepare them for the paradigm shift in AI-based learning. The LPTK (Education Personnel Education Institute) curriculum needs to integrate technology-based training so that prospective teachers are able to design adaptive and innovative learning. The sustainability of this innovation is highly dependent on the readiness of educational actors to adapt to the ever-evolving digital era.

CONCLUSION

The application of artificial intelligence in adaptive learning systems has been shown to significantly improve the understanding of elementary school students with an even distribution of improvement among students, making it a finding that distinguishes this study from previous studies that focused more on the level of higher education.

This research makes a conceptual contribution in strengthening the role of AI-based adaptive technology as an effective pedagogical approach at the primary education level, while presenting a learning method model that combines real-time data analytics and learning personalization at a micro scale.

The scope of research is limited to one region and limited population is a major limitation, so the direction of further research needs to expand the geographical and social context, explore the long-term influence of AI on children's learning development and its integration with teacher pedagogical approaches in various school characteristics.

AUTHORS' CONTRIBUTION

Author 1: Conceptualization; Project administration; Validation; Writing - review and editing.
Author 2: Conceptualization; Data curation; In-vestigation.

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