



# Neuroscience-Based Education in The Era of Artificial Intelligence: Enhancing Cognitive Development Through Adaptive Learning Technologies

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## ABSTRACT

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Rapid advancements in education demand technological innovations to enhance learning quality. This study explores the role of neuroscience-based education in improving students' cognitive development through adaptive learning technology in the AI era. Using a qualitative approach with a case study design, the research involved the Principal, curriculum and student affairs deputies, teachers, and students. Data were collected through observation, in-depth interviews, and documentation, then analyzed through data reduction, presentation, and conclusion. Findings reveal that neuroscience-based adaptive learning technology enhances cognitive development by addressing individual learning styles. Intelligent learning systems enable personalized education, allowing students to progress at their own pace, improving learning efficiency and effectiveness. Beyond academic skills, these technologies foster learning motivation, engagement, and outcomes. This study underscores the importance of integrating neuroscience principles into AI-driven education to support holistic cognitive development and create engaging, personalized learning experiences, offering a fresh perspective on the intersection of neuroscience, technology, and education.

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## INTRODUCTION

In the era of artificial intelligence (AI), neuroscience-based education is relevant because of its ability to understand how the human brain learns and

develops. Adaptive learning technology, designed based on neuroscience principles, is able to adjust teaching methods to the individual needs of students (Firyaa et al., 2024). For example, digital education platforms that use AI algorithms can analyze students' learning patterns, provide materials that are appropriate to their abilities, and help accelerate cognitive development (Sulaeman & Mahpudin, 2024). This not only increases the effectiveness of learning but also reduces the gap in education by providing a more personalized learning experience for each student, including in remote areas (Supriatna, 2024). However, the implementation of neuroscience-based education in the AI era also presents social challenges. Access to adaptive learning technology is often limited to groups with adequate digital infrastructure, thus widening the digital divide between developed and underdeveloped regions (Dwi Mukti, 2023). In addition, the adaptation of this technology requires a good understanding from educators, who are often still not sufficiently trained in using AI in teaching (Nisa' et al., 2024)(Mira Lestari et al., 2024). Therefore, collaboration between the government, educational institutions, and the technology sector is vital to ensure that all levels of society can feel the benefits of this technology.

Several previous studies, such as those conducted by (Mambu et al., 2023), have shown that AI-based adaptive learning technology is effective in accelerating conceptual understanding by adjusting teaching materials based on individual learning styles. However, on the other hand, (Mardiah et al., 2022) revealed that a neuroscience-based approach, supported by analysis of brain activity patterns by AI, is able to overcome learning difficulties more efficiently), which emphasizes the need for human intervention in the learning process to maintain balance. Another study by (Lazuardi & Rahmadi, 2020) explored the positive impact of AI on early childhood cognitive development, primarily through adaptive programs designed to stimulate the brain according to developmental stages. Meanwhile, research by (Nurachmy Sahnir et al., 2023) found that AI-based adaptive learning in the STEM field not only improves learning outcomes but also creates a more engaging and immersive learning experience. Although various studies have explored the potential of neuroscience in supporting AI-based learning, further research is needed on the ethical and sustainable application of adaptive learning technology in educational institutions.

This study attempts to address the gap in the literature by analyzing the application of artificial intelligence (AI)-based adaptive learning technology in neuroscience education to enhance students' cognitive development. Most previous studies have focused on the potential of adaptive learning technology in improving learning outcomes and personalizing learning. Still, few have examined how this technology can be applied while considering neuroscience principles and ethical values. Therefore, this study aims to explore how the application of AI-based adaptive learning technology can be in line with neuroscience approaches to support cognitive development while considering

ethical dimensions such as fairness of access, algorithm transparency, and bias avoidance. With an approach that integrates neuroscience, AI, and ethics, this study offers a new contribution to designing learning technologies that are not only innovative but also inclusive and based on scientific evidence. The novelty lies in the effort to combine neuroscience insights with AI-based adaptive learning technology, which has great potential to support cognitive development through personalized, interactive, and data-driven learning experiences. However, the use of this technology also poses ethical challenges, such as the risk of dependence on algorithms, potential bias in learning recommendations, and access gaps that can exacerbate educational inequalities (Virgin Sabrina El-Islamy, Samsul Susilawati, 2023).

Based on the above, this study argues that neuroscience-based education in the era of artificial intelligence (AI) offers a revolutionary approach to improving students' cognitive development through adaptive learning technology; by leveraging insights from neuroscience, AI-based learning systems can be designed to adapt educational methods and content to individual cognitive needs and learning styles (S. E. Susanti, 2021). This technology enables real-time analysis of student responses, such as attention levels, comprehension, and motivation, thus providing a more personalized and practical learning experience (Baharun, 2023) (Fauzatul Rohmah & Anam, 2023). In addition, AI-based adaptive learning can help identify knowledge gaps early and provide relevant feedback, which not only improves academic outcomes but also supports the development of critical skills in the digital age (Isdayani et al., 2024). This makes the integration of neuroscience and AI an essential foundation for creating inclusive, efficient, and individual-based education.

## RESEARCH METHOD

This study employs a qualitative research approach with a case study design to explore the application of neuroscience-based education in the era of artificial intelligence. The case study method was selected to gain an in-depth, contextual, and holistic understanding of how adaptive learning technology, grounded in neuroscience principles, can enhance students' cognitive development. The research focuses on examining adaptive learning strategies, the personalization of the learning process through AI, and the integration of these technologies into the curriculum to foster more meaningful and effective learning outcomes.

The research was conducted at SMP Nurul Huda Peleyan Kapongan Situbondo, focusing on individuals directly involved in the educational process. The primary informants included the Principal, Deputy of Curriculum, Deputy of Student Affairs, teachers, and students. Data sources were categorized into two main groups: efforts to integrate adaptive learning technologies, such as AI-based learning applications and personalized learning programs, and the impact of these efforts on student outcomes, such as material comprehension, learning

motivation, and critical thinking skills.

Data collection was carried out through observation, in-depth interviews, and documentation to obtain a comprehensive understanding of the phenomena (Pérez Dávila, 2020). Observations were made to directly see the implementation and effects of neuroscience-based adaptive learning, while interviews captured the perceptions and experiences of stakeholders. Documentation provided secondary data, such as reports and policy evaluations, to support analysis. The collected data were analyzed using Miles and Huberman's techniques, involving data condensation, data display, and verification through triangulation and member-checking to ensure the reliability and validity of the findings.

## RESULT AND DISCUSSION

### Result

This study focuses on two main aspects of the influence of neuroscience-based adaptive learning technology on students' cognitive development, namely the influence of neuroscience-based adaptive learning technology on students' cognitive development and the implementation of artificial intelligence in adaptive learning to increase student engagement and motivation. The results of this study reveal how neuroscience-based adaptive learning technology, which integrates neuroscience principles in curriculum and material design, can improve students' understanding and memory through a more personalized approach that is in accordance with students' cognitive development stages. The discussion of these results will outline the positive impacts of both aspects on the quality of education, the development of student's cognitive skills, and the increasing effectiveness of learning in the digital era based on advanced technology.

### **The Influence of Neuroscience-Based Adaptive Learning Technology on Students' Cognitive Development**

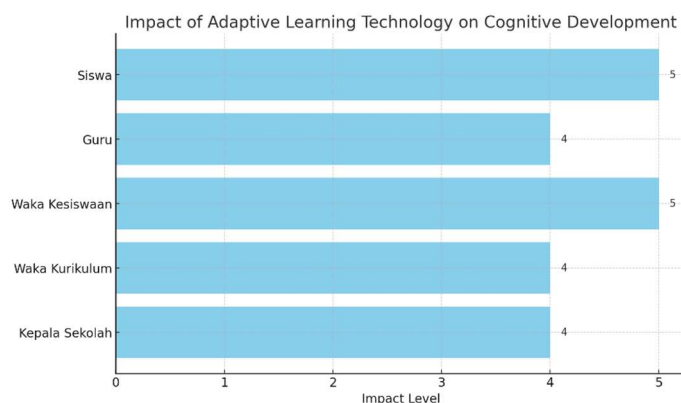
Tables The results of the interview with the Principal explained that the implementation of neuroscience-based adaptive learning technology in schools aims to support students' cognitive development by adjusting the learning process to individual learning styles. *"With this technology, we can ensure that each student gets material that suits their abilities and learning speed."* He emphasized that adaptive technology provides opportunities for students to learn more effectively and efficiently and increases the absorption of material according to the stage of students' cognitive development. This statement is in line with the explanation of the Deputy Head of Curriculum, who said, *"The implementation of this technology greatly supports a flexible curriculum, allowing students to learn according to their needs and abilities."* The Deputy Head of Curriculum added that neuroscience-based technology can monitor students' cognitive development more accurately, provide timely feedback, and adjust the material provided according to the student's development level.

The connection between the Principal and the Vice Principal for Curriculum interviews was also strengthened by an interview with the Vice Principal for Student Affairs, who stated, *"Students with special needs, or those who have different learning speeds, are greatly helped by this technology. They can get materials that are tailored to their cognitive abilities."* The Vice Principal for Student Affairs explained that this technology allows students who have difficulty processing information to get a more appropriate approach to their condition, thus helping to reduce the gap between fast and slow learners.

The interviewed teacher also provided a view that was in line with both statements, *"With this technology, I can more easily manage the variation of abilities in the class. Each student gets learning that is tailored to their cognitive needs,"* he added that adaptive technology allows for the modification of teaching approaches based on individual student responses so that cognitive development can be optimally encouraged. Furthermore, the interviewed student also shared his experience of using adaptive learning technology. *"Learning is more enjoyable because the material given is in accordance with my abilities. If there is something difficult, I can learn in a way that is easier to understand."* This statement confirms that neuroscience-based technology provides a more interactive and personalized learning experience tailored to students' cognitive needs without feeling burdened by material that is too difficult or too easy.

Interviews with the Principal, Vice Principal of Curriculum, Vice Principal of Student Affairs, teachers, and students revealed the importance of implementing neuroscience-based adaptive learning technology in schools to support students' cognitive development. The Principal explained that this technology enables learning that is tailored to individual learning styles and speeds, ensuring that each student receives material that is appropriate to their abilities. This was reinforced by the Vice Principal of Curriculum, who emphasized the flexibility of technology in supporting a curriculum that can adapt to students' needs and abilities and provide timely feedback according to cognitive development. This technology is recognized as being able to monitor and adjust learning materials to students' development more accurately.

The views of the Vice Principal of Student Affairs and teachers are also in line, stating that this technology provides excellent benefits for students with special needs or who have different learning speeds. Adaptive technology helps reduce the gap between fast and slow learners by providing an approach that suits each student's condition. The students themselves feel more comfortable and motivated because the material provided is tailored to their abilities. Students feel that learning is more fun and interactive, with a more personalized experience that allows them to learn according to their cognitive developmental stage without feeling burdened.



**Figure 1. Impact of Adaptive Learning Technology on Cognitive Development**

The bar chart above illustrates the impact of neuroscience-based adaptive learning technology on students' cognitive development based on interviews with various parties in the school. The scores on the chart show how much impact each role (Principal et al. of Curriculum, Vice Principal of Student Affairs, Teachers, and Students) feels on learning.

first, the Principal and Deputy Principal for Curriculum Felt that this technology greatly supported the effectiveness of learning and curriculum flexibility, with a score of 4 indicating a significant impact. Second, the Deputy Principal for Student Affairs considered the technology to be very helpful to students with special needs or different learning speeds, with a score of 5 indicating a very strong impact. Third, the teacher felt that this technology made it easier to manage the variety of student abilities in the class, scoring 4 out of 5. Fourth, students directly benefit because the learning material was tailored to their abilities, providing a more enjoyable and practical learning experience, with a score of 5.

This score shows that neuroscience-based adaptive learning technology significantly improves students' cognitive development according to their individual needs and learning styles.

### **Implementation of Artificial Intelligence in Adaptive Learning to Increase Student Engagement and Motivation**

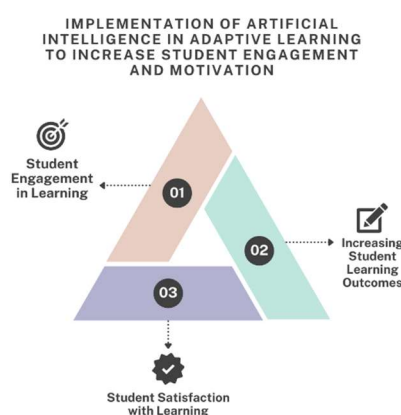
The following are the research results that show Implementation of artificial intelligence in adaptive learning to increase student engagement and motivation in SMP Nurul Huda Peleyan Kapongan Situbondo:

**Table 1. Interview Result Data Implementation of Artificial Intelligence in Adaptive Learning to Increase Student Engagement and Motivation**

<b>Informant</b>	<b>Statement</b>	<b>Code</b>
Headmaster	"We see artificial intelligence as a tool to provide more personalized learning to students, which in turn increases student engagement."	Personal Learning
Deputy Head of Curriculum	"Adaptive learning with AI allows for a curriculum that is more flexible and tailored to	Flexible Curriculum

Curriculum	each student's needs, reducing reliance on standard methods."	
Deputy Principal for Student Affairs	"AI can increase student motivation by providing faster and more accurate feedback, as well as materials tailored to their abilities."	Motivation and Feedback
Teacher	"In my class, we use a platform that can assess students' abilities and provide additional materials automatically. Students can learn according to their level of understanding, and I can monitor their progress in real-time."	AI Based Learning
Student	Learning with AI feels more interesting because I can learn at my own pace, and can get the material I need."	Interesting learning

In interviews with various parties in the school, it was seen that artificial intelligence (AI) is considered a tool with great potential to improve the learning experience of students. The Principal stated that AI allows for more personalized learning, which, in turn, can increase student engagement. The Vice Principal of Curriculum added that the use of AI in adaptive learning allows the curriculum to be more flexible and tailored to students' needs, reducing reliance on standard methods. The Vice Principal of Student Affairs also emphasized that AI can speed up and improve the quality of feedback to students, as well as provide materials tailored to each person's abilities, which contributes to increased student motivation. The interviewed teacher explained that using an AI-based platform to automatically assess students' abilities and provide additional materials according to their level of understanding. This allows students to learn in a way that is more appropriate to their pace, and teachers can monitor student progress in real time. Finally, students stated that AI-based learning feels more attractive because they can learn at a pace that suits their needs and get relevant materials to support understanding. Overall, these interviews illustrate how AI can support more personalized, flexible, and engaging learning, as well as increase student engagement, motivation, and learning outcomes.



**Figure 2. Implementation of Artificial Intelligence in Adaptive Learning to Increase Student Engagement and Motivation**

The image 2. that the implementation of artificial intelligence (AI) in adaptive learning can increase student engagement and motivation by providing a learning experience that is tailored to the needs and abilities of each student. AI enables more personalized learning, where materials and methods are automatically adjusted to maximize student understanding, making students more involved in the learning process. Improved student learning outcomes can be achieved because AI can provide fast and accurate feedback and offer exercises that are more appropriate to the level of student understanding, reinforcing concepts that have not been mastered. In addition, student satisfaction with learning increases because students feel individually supported, more appreciated in the learning process, and gain more enjoyable and relevant experiences, which encourages higher self-confidence and motivation in learning.

## **Discussion**

The impact of neuroscience-based adaptive learning technologies on students' cognitive development is increasingly significant in modern education, given advances in scientific understanding of how the human brain learns (Maulita et al., 2022). These technologies are designed to adapt the learning process to the needs and learning styles of each student, allowing them to develop at a pace and manner that best suits their cognitive potential (Herdi, 2024). Through a neuroscience-based adaptive approach, students can experience more effective learning, which encourages the development of students' cognitive abilities, such as problem-solving, creativity, and deeper conceptual understanding (Hasanah, 2024). This method not only improves learning outcomes but also supports students' ability to adapt to complex learning challenges, accelerates the process of internalizing information, and enhances critical thinking skills needed in an ever-evolving world (Rizal, 2023).

The implementation of artificial intelligence (AI) in adaptive learning plays a vital role in increasing student engagement and motivation, especially in the context of responsive and innovative education (Widodo, 2024). The use of AI allows educators to analyze student learning data in real-time, identify learning patterns, and provide feedback that is tailored to individual student needs (Hidayat et al., 2024) (Hasanah, 2024). From an adaptive learning perspective, this technology supports a personalization process that can increase student engagement through relevant learning experiences that are tailored to their learning pace and style (Chen & Zhang, 2023). In addition, lecturers who are proactive in integrating AI into teaching methods can create a more engaging and efficient learning environment, which in turn contributes to increased student motivation and learning outcomes (A. Susanti et al., 2024).

## CONCLUSION

Neuroscience-based education in the era of artificial intelligence (AI) offers significant potential to enhance students' cognitive development through adaptive learning technology. This approach combines an understanding of brain processes with the ability of technology to tailor learning experiences to individual students' needs. Using data generated by AI systems, this technology can design learning materials and methods that dynamically adjust to each student's level of difficulty, learning style, and pace of cognitive development. This can accelerate the learning process and enable students to reach their maximum potential in a more personalized and effective way. Theoretically, the application of neuroscience and AI-based education enriches learning theories that emphasize the importance of learning experiences tailored to individual characteristics. Concepts such as scaffolding and the zone of proximal development (ZPD) can be strengthened by the use of adaptive technology, enabling the achievement of optimal cognitive development. On the other hand, cognitive theories related to information processing and memory are also expanded with the integration of technology that can accelerate the processing and storage of information through more efficient learning. Further implications include the need for updates in curriculum and educational strategies that utilize both of these elements to optimize student learning in the digital era.

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