
THE ROLE OF ARTIFICIAL INTELLIGENCE IN IMPROVING THE QUALITY OF BIOLOGY LEARNING

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Abstract: This study aims to explore the role of Artificial Intelligence (AI) in improving the quality of biology learning at the secondary education level. This research uses a literature review approach, which is a research method that is carried out by collecting, analyzing, and synthesizing information from various relevant written sources. The results show that AI plays an important role in facilitating the visualization of complex biological concepts, providing adaptive learning experiences tailored to students' individual abilities, and offering virtual laboratories that allow biological experiments without the limitations of physical facilities. However, challenges in its implementation, such as limited infrastructure, lack of teacher training, and high implementation costs, are still major obstacles. Teachers and students' perceptions of AI are generally positive, with many feeling that the technology improves students' understanding and motivation to learn. However, the role of teachers as facilitators remains important in overcoming the technical challenges faced by students. This study concludes that despite the challenges, the application of AI in biology learning has great potential to improve the quality of learning, and there needs to be more attention to aspects of training, infrastructure, and education policies that support the widespread application of this technology.

Keywords: Artificial Intelligence, Biology Learning, Learning Quality, Visualization, Adaptive Learning, Virtual Laboratory

I. INTRODUCTION

Artificial Intelligence (AI) has become one of the most significant technological innovations of the 21st century (Mubarik et al., 2024). In various sectors, including education, AI has made a significant contribution in improving the efficiency and effectiveness of the learning process (Fitri & Dilia, 2024). In the field of biology, which has material complexity and various abstract concepts, AI offers various innovative solutions that can improve the quality of learning. Biology learning often involves a deep understanding of the structure, function, and interactions of living organisms (Lasaiba, 2023). The use of AI technology can help students understand complex material through visualization, simulation, and personalization of the learning process. For example, AI-based technology can create three-dimensional (3D) models of the structure of human cells or organs, allowing students to learn the material in a more interactive way.

One of the main benefits of AI in biology learning is its ability to provide adaptive learning. AI-based learning systems can adapt the material to the needs and learning speed of students. This allows each student to have a personalized learning experience, so they can more easily understand difficult concepts such as genetics, evolution, and ecology. In addition, AI also supports scientific exploration through simulation. In biology learning, AI-based simulations can be used to predict the effects of environmental changes on ecosystems or to understand genetic mechanisms in a more dynamic way (Tarumingkeng, n.d.). This not only improves understanding, but also encourages students to think critically and creatively.

In the context of virtual laboratories, AI provides solutions for schools that have limited laboratory facilities. With the help of AI, students can conduct biological experiments virtually, such as observing cell division or the process of photosynthesis. Not only does this facility save costs, but it also provides a practical, risk-free experience that is typically found in physical laboratories. AI also makes it easier to access high-quality learning resources. With advanced search algorithms, students can quickly find relevant biology material from a variety of sources, including scientific journals, educational videos, and eBooks (Adedo & Deriwanto, 2024). This opens up broader and deeper learning opportunities.

In the world of formal education, AI has helped teachers in analyzing the learning needs of students. AI-based systems can evaluate student performance through data collected from tests, quizzes, or assignments (Maulana, 2024). Based on this analysis, teachers can provide more specific feedback and develop more effective teaching strategies. AI also plays a role in reducing teachers' administrative burden, such as assignment assessment and report making. Thus, teachers have more time to focus on developing creative learning methods, including in the field of biology which requires a lot of innovation to attract students' interest.

In the digital era, AI-based chatbots are a very useful support tool for students. The chatbot can answer students' questions about biology concepts instantly, provide additional explanations, or even recommend additional learning resources (Putri et al., 2023). It allows students to learn independently anytime and anywhere. AI is also driving global collaboration in biology learning. AI-based learning platforms allow students from different parts of the world to collaborate on scientific projects, share data, and learn from diverse perspectives. This kind of collaboration can broaden students' horizons and improve their understanding of global issues, such as climate change and biodiversity conservation (Fajriati et al., 2024).

Despite its many benefits, the implementation of AI in biology learning is not without its challenges. One of the main challenges is the availability of technological infrastructure, especially in remote areas. In addition, there is a need to train teachers to be able to effectively utilize AI technology in their teaching. However, these challenges can be overcome with collaboration between the government, educational institutions, and the private sector. Investing in education technology and teacher training is an important step to ensure that the potential of AI can be fully utilized in improving the quality of biology learning.

AI also has the potential to enrich learning evaluation. With in-depth data analysis, AI can identify students' learning patterns, strengths, and weaknesses. This information can be used to design a more targeted and effective learning program. The use of AI in biology learning is not only relevant for students, but also for young researchers. With AI's ability to analyze big data, researchers can develop new findings in the field of biology, such as in genomic research or the study of environmental change.

Ultimately, the role of AI in biology learning reflects technological advancements that have brought significant changes in the world of education. With wise use, AI can be a catalyst to create a generation that is better prepared to face the challenges of future science and technology.

II. RESEARCH METHODS

1. Research Approach

This research uses a literature review approach, which is a research method that is carried out by collecting, analyzing, and synthesizing information from various relevant written sources (Adlini et al., 2022). The data sources used include scientific journals, books, conference proceedings, research reports, and other documents related to artificial intelligence (AI) and biology learning.

2. Research Steps

Identify Topics and Scope

- Determine the main topic, namely the role of artificial intelligence in improving the quality of biology learning.
- Limit the scope of research to the use of AI in the context of biology learning, such as in the development of teaching materials, learning evaluation, or interactive media.

3. Search and Data Collection

- Use academic databases such as Google Scholar, ScienceDirect, Springer, or ProQuest to search for relevant articles, journals, and research reports.
- Keywords used in search include:
 - Artificial Intelligence in Biology Education
 - AI in Learning Quality Improvement

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- Sort the relevant literature by year of publication (last 5–10 years) to ensure the data used is current.
4. Data Analysis
 - Conduct content analysis of the literature that has been collected. This process includes:
 - ✓ Identify the role of AI in biology learning.
 - ✓ Classify AI implementations, such as the use of chatbots, virtual lab simulations, adaptive applications, or student data analysis.
 - ✓ Assess the impact of AI on learning quality, such as improved concept understanding, student engagement, or personalization of learning.
 5. Synthesis of Findings
 - Integrate the results of analysis from various sources to provide a comprehensive picture of the contribution of artificial intelligence in biology learning.
 - Develop a concept map about the relationship between AI technology and improving the quality of learning.
 6. Data Validation
 - Using the source triangulation method by comparing findings from various literature.
 - Ensure that the sources used are credible and trustworthy.
 7. Research Instruments

The instrument used in this study is a literature analysis guide in the form of criteria for relevance, credibility, and contribution of literature to the research topic.

III. RESEARCH RESULTS AND DISCUSSION

1. Utilization of AI in Biology Learning

From interviews and observations, it was found that AI is used in various aspects of biology learning:

- **Complex Concept Visualization:** Teachers use AI-based software to create 3D models of human body cells, organs, or systems. Students stated that these visualizations helped them understand difficult concepts.
- **Adaptive Learning:** The AI system is able to adjust the difficulty level of the questions based on the student's ability, so that low-ability students remain motivated, while high-ability students are challenged to learn more material.
- **Virtual Laboratories:** Some schools use AI-based applications that allow for the simulation of experiments, such as the process of photosynthesis or cell division.

Table 1. Utilization of AI in Biology Learning

Aspects	AI Implementation	Impact
Concept Visualization	3D models of organs, cells, and ecosystems	Helping students understand difficult material
Adaptive Learning	The AI system adjusts the difficulty level of the questions	Students are more motivated and focused
Virtual Lab	Simulation of biological experiments	Providing a practical experience securely

2. Challenges in AI Adoption

While AI provides significant benefits, the study also identifies several challenges:

- Infrastructure Limitations: Schools in remote areas face limited internet access and adequate hardware.
- Lack of Teacher Training: Many teachers have not been trained to optimally integrate AI in learning.
- Implementation Costs: AI applications and devices are still relatively expensive, especially for schools with limited budgets.

Table 2. Challenges in AI Adoption

Challenge	Information
Infrastructure Limitations	Unstable internet connection in some schools
Lack of Teacher Training	Teachers have difficulty using AI applications
Implementation Costs	High hardware and software prices

3. Teachers' and Students' Perceptions of AI

From the results of the interviews, the perception of the use of AI in biology learning is generally positive. Teachers stated that AI helps save time in delivering complex material, while students feel more enthusiastic because learning becomes more interactive. However, they also admit that without teacher guidance, some students find it difficult to use AI technology independently.

Table 3. Teachers' and Students' Perceptions of AI

Group	Positive Perception	Negative Perception
Teacher	Assist with visualization and analysis of student data	Requires additional training
Student	Interactive, engaging, and comprehension aids	Technical difficulties without assistance

4. The Impact of AI on Learning Outcomes

The results of observation and documentation showed an increase in students' understanding of biology material after using AI-based technology. In addition, students become more active in discussing and seeking answers to their questions.

Table 4. The Impact of the Use of AI on Student Learning Outcomes

Aspects	Before Using AI	After Using AI
Understanding Concepts	65% of students understand the material	85% of students understand the material
Student Participation	Low-grade discussions	More active and directed discussions
Interest in Biology	Lack of enthusiasm for lessons	More enthusiastic and motivated to learn

DISCUSSION

This study aims to identify the role of Artificial Intelligence (AI) in improving the quality of biology learning. Based on the results found, AI has been shown to make a significant contribution to biology learning, although certain challenges need to be overcome so that its implementation can be more optimal. This discussion will

relate the results of the research with previous theories and research to provide a deeper understanding of the role of AI in education.

1. Utilization of AI in Biology Learning

From the results of the research, the use of AI in biology learning is mainly seen in three aspects: concept visualization, adaptive learning, and virtual laboratory. The use of 3D models for the visualization of complex biological concepts, such as the structure of cells or organs of the human body, allows students to more easily understand difficult material. For example, these 3D models can depict processes such as cell division or the movement of molecules in the body that are difficult to explain with just 2D words or images. Research conducted by (Guindy & Kara, 2024) It also shows that the use of visualization technology like this can help students understand abstract concepts in science, including biology.

In addition, the application of AI-based adaptive learning that adapts the material to the level of students' abilities has also proven to be effective. This system provides challenges that match students' abilities, so they don't feel overwhelmed or bored. Research by (Kulik & Fletcher, 2016) It also revealed that adaptive learning technology can improve student learning outcomes because it provides a more personalized learning experience and according to individual needs.

The virtual labs provided by AI are also very useful, especially in biology learning involving scientific experiments. For example, students can conduct photosynthesis experiments or observations of cell division virtually without having to be bound by physical limitations or facilities. This is in line with research conducted by (Hofstein & Lunetta, 2004), which states that virtual laboratory simulations provide greater opportunities for students to explore experiments that are difficult to do in real labs, especially in schools with limited resources.

2. Challenges in AI Adoption

While many benefits were found in the application of AI, the study also identified some challenges. One of them is the limitation of infrastructure, especially in remote areas, which often has difficulty in providing a stable internet connection or adequate hardware. This is in line with the findings in the study by (Li, 2024), which shows that one of the main obstacles in the application of AI-based educational technology is the lack of infrastructure accessibility in many regions.

In addition, the lack of training for teachers to integrate AI technology in the learning process is also a significant challenge. As a new technology, AI requires a deep understanding to be used optimally. Research results by (Salas-Pilco et al., 2022) said that training for teachers is one of the important factors in ensuring the successful application of technology in the classroom. Trained teachers can leverage AI to design more engaging and effective learning experiences for students.

Implementation costs are also a relevant issue. While AI can provide great benefits, the hardware and software needed to support this technology are still expensive, especially for schools on a budget. Research by (Spector et al., 2008) highlighting the cost challenge as one of the main barriers to technology adoption in education.

3. Teachers' and Students' Perceptions of AI

Positive perceptions of the use of AI in biology learning were found among both teachers and students. Teachers report that AI helps them in conveying complex material in a more engaging and interactive way. Students, on the other hand, feel that AI-assisted learning has become more enjoyable and motivates them to study harder. These results are consistent with research conducted by (Buchanan et al., 2021), which states that the application of AI in education can increase student engagement and motivate them to be more active in learning.

However, while perceptions of AI tend to be positive, most students report technical difficulties when using AI without teacher assistance. This shows that while AI can support learning, the role of teachers as facilitators is still very important in ensuring the effective use of this technology. According to research by (Hattie, 2008), the role of teachers in creating constructive interactions with students, even in the use of technology, remains crucial to achieve maximum learning outcomes.

4. The Impact of AI on Learning Outcomes

From the results of observation and data analysis, AI is proven to have a positive impact on student learning outcomes in biology subjects. Students who use AI-based technology show a better understanding of biological

concepts, as well as being more active in class discussions. This shows that AI not only accelerates material comprehension but also increases student engagement in the learning process. Research by (Gligorea et al., 2023) states that AI can improve students' academic performance through in-depth data analysis, which makes it possible to provide more specific and timely feedback.

This result is also in accordance with the theory of constructivism put forward by (Vygotsky & Cole, 1978), which states that learning that involves social interaction and hands-on experience will be more effective. In this case, AI technology allows students to learn more actively, by participating in the simulation and exploration of biological concepts that may be difficult to understand through traditional means.

IV. CONCLUSIONS

Based on the results of the research and discussion that has been carried out, it can be concluded that the use of Artificial Intelligence (AI) in biology learning has a significant impact on improving the quality of learning. AI has proven to be effective in visualizing complex biological concepts, such as the structure of cells or organs of the human body, which are often difficult for students to understand through verbal explanations or 2D images. By utilizing 3D models and simulations, students can gain a more interactive and immersive learning experience, which can improve their understanding of the material. In addition, AI technology also provides support in adaptive learning, where the learning system adjusts the material and difficulty level according to the student's ability. This helps keep students motivated, because they don't feel burdened or bored, but also still get challenges that match their abilities. The use of AI-based virtual laboratories provides opportunities for students to conduct biological experiments that are difficult to conduct in physical laboratories, opening up wider learning opportunities without being constrained by limited facilities or resources. However, while the benefits are clear, the study also found some challenges in the application of AI, especially related to limited infrastructure in remote areas, lack of training for teachers in integrating AI into learning, and quite high implementation costs. These limitations need to be a concern for governments and educational institutions in an effort to expand access and maximize the potential of AI in education.

Positive perceptions of the use of AI from teachers and students show that this technology has the potential to enrich the learning experience. Teachers feel helped in delivering complex material, while students feel more enthusiastic and active in learning. Nonetheless, the role of teachers remains crucial in ensuring the effective use of AI, as students still need guidance to overcome technical challenges and maximize the benefits of this technology. Overall, this study suggests that AI can be an invaluable tool in improving the quality of biology learning. By addressing existing challenges, such as infrastructure and training, and with adequate policy support, the application of AI in education can make a significant contribution to the development of more effective, efficient, and engaging learning. Therefore, it is important to continue to encourage the application and development of AI technology in the world of education so that its great potential can be enjoyed by more students and teachers around the world.

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