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The effect of artificial intelligence on students learning outcomes and motivation in biology: A literature review

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Abstract. The transformation of education in the 21st century demands technology-based innovation to strengthen learning effectiveness, particularly in Biology, which contains abstract concepts and requires strong visualization. One innovation that plays a crucial role in this context is the use of Artificial Intelligence (AI), which can support concept visualization and adaptive learning interactions. This study aims to analyze the implications of Artificial Intelligence (AI) on student learning outcomes and motivation in Biology through the Systematic Literature Review (SLR) method. The article selection process was carried out systematically using the PRISMA model for publications published between 2020 and 2024 in the Google Scholar database, resulting in 10 relevant articles. The results of the content analysis showed that AI integration consistently had a positive impact on student conceptual understanding, motivation, and engagement in Biology learning. Various AI-based media, such as chatbots, Google Lens, SUNO AI, PlantNet, and digital e-modules, have proven effective as facilitators that support active, adaptive, and personalized learning. In addition to improving cognitive learning outcomes, the use of AI also contributes to increasing digital literacy and student self-confidence. Thus, it can be concluded that AI functions not only as a learning tool but also as a strategic pedagogical solution in creating a quality biology learning ecosystem in the era of Society 5.0.

Abstrak. Transformasi pendidikan pada abad ke-21 menuntut adanya inovasi berbasis teknologi untuk memperkuat efektivitas pembelajaran, khususnya pada mata pelajaran Biologi yang memuat konsep-konsep abstrak dan membutuhkan visualisasi yang kuat. Salah satu inovasi yang berperan penting dalam konteks tersebut adalah pemanfaatan Artificial Intelligence (AI) yang mampu mendukung visualisasi konsep serta interaksi pembelajaran yang adaptif. Penelitian ini bertujuan untuk menganalisis implikasi Artificial Intelligence (AI) terhadap hasil belajar dan motivasi siswa pada mata pelajaran Biologi melalui metode Systematic Literature Review (SLR). Proses seleksi artikel dilakukan secara sistematis menggunakan model PRISMA terhadap publikasi yang terbit pada rentang tahun 2020–2024 di basis data Google Scholar, sehingga diperoleh 10 artikel yang relevan. Hasil analisis isi (content analysis) menunjukkan bahwa integrasi AI secara konsisten memberikan dampak positif terhadap pemahaman konsep, motivasi, dan keterlibatan siswa dalam pembelajaran Biologi. Berbagai media berbasis AI, seperti chatbots, Google Lens, SUNO AI, PlantNet, dan e-modul digital, terbukti efektif sebagai fasilitator yang mendukung pembelajaran aktif, adaptif, dan personal. Selain meningkatkan hasil belajar kognitif, pemanfaatan AI juga berkontribusi terhadap peningkatan literasi digital serta kepercayaan diri siswa. Dengan demikian, dapat disimpulkan bahwa AI tidak hanya berfungsi sebagai alat bantu pembelajaran, tetapi juga sebagai solusi pedagogis strategis dalam menciptakan ekosistem pembelajaran Biologi yang berkualitas di era Society 5.0.

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Introduction

Education, as a fundamental right of every citizen, plays a strategic role in optimizing individual potential across cognitive, affective, and social domains. The learning process emphasizes not only the acquisition of knowledge but also the cultivation of students' mindsets, attitudes, and behaviors to equip them for life's challenges. The 12-year compulsory education policy represents a strategic government measure to enhance the quality of human resources through sustainable and inclusive education (Alfy et al., 2023; Santoso, 2022). Within this process, the interaction among students, teachers, and the learning environment plays a crucial role in fostering communication skills, collaboration, and self-confidence.

Rapid advancements in science and technology require the education sector to adapt by adopting more innovative learning approaches. The concept of Society 5.0 emphasizes human-centered technology utilization, where technology does not replace human roles but rather supports the enhancement of quality of life and learning processes (Muhtadin et al., 2022). The challenges of this era demand the mastery of data literacy, technology literacy, and human literacy, which encompasses critical thinking, communication, and creativity skills (Santoso, 2022; Usman et al., 2025). Therefore, school instruction must be systematically designed to develop these competencies in a balanced manner.

Biology education presents complex challenges due to the abstract nature of the subject matter, which necessitates visualization and profound conceptual understanding. The implementation of digital learning has been reported to enhance student engagement and learning outcomes compared to conventional methods (Fadhilah, 2022; Nadia et al., 2025). Furthermore, innovative approaches such as STEAM encourage students to think critically and creatively in solving biological problems through the integration of science and technology. Nevertheless, the utilization of conventional digital media remains limited in its ability to provide adaptive and personalized learning tailored to individual student needs.

The advancement of digital technology has further driven the adoption of Artificial Intelligence (AI) across various sectors, including education. The utilization of AI in instruction enables systems to analyze student learning patterns, provide immediate feedback, and tailor content to individual capabilities (Karyadi, 2023; Pratita & Suryanto, 2024). Numerous studies indicate that the integration of AI in Biology education contributes to enhanced conceptual understanding, learning motivation, and student engagement through adaptive interactions, such as chatbots and visual identification applications (Faldi et al., 2023; Haidir et al., 2024).

While research on the utilization of AI in Biology education continues to evolve, the majority of studies remain focused on media development or testing within specific contexts and subject matter. Studies systematically summarizing the impact of AI on student learning outcomes and motivation in Biology particularly within the context of Indonesian education remain relatively limited. This situation underscores the need for a comprehensive analysis to identify patterns of AI utilization and its contribution to enhancing the quality of Biology instruction**.**

Accordingly, this study aims to analyze the implications of Artificial Intelligence (AI) on student learning outcomes and motivation in Biology education through a Systematic Literature Review (SLR). This review is expected to offer a comprehensive overview of research trends, the effectiveness of AI utilization, and its implications as a pedagogical solution for fostering adaptive, contextual, and relevant Biology instruction aligned with the demands of the Society 5.0 era.

Research Methods

1) Data type

This study employs the Systematic Literature Review (SLR) method to comprehensively examine the implications of Artificial Intelligence (AI) on student learning outcomes and motivation in Biology. The SLR method is designed to be systematic, explicit, and reproducible for identifying, evaluating, and interpreting research findings relevant to specific research questions (Lusianti et al., 2024). The literature search was conducted using the keywords "artificial intelligence," "learning outcomes," "student motivation," and "biology learning." Article selection was performed systematically using the PRISMA model, encompassing the stages of identification, screening, eligibility, and inclusion. The adoption of the PRISMA model aims to enhance the transparency and accuracy of the article selection process within literature reviews (Fajeriadi et al., 2024). From a total of 1,010 articles identified in the initial stage, 10 final articles were obtained that met the inclusion criteria and were deemed suitable for in-depth analysis. The article selection process in this study was based on predetermined inclusion and exclusion criteria to ensure the relevance and quality of the data sources. The details of these criteria are presented in Table 1.

Table 1 Inclusion and exclusion criteria for articles in the SLR study

Inclusion Criteria	Exclusion Criteria
Studies directly related to the research topic. Articles published within the last five years (2020-2024). Studies employing empirical approaches or methods. The article is available in full access so that it can be analyzed thoroughly. Published in a recognized national journal.	Non-empirical studies. Publications written in languages other than Indonesian or English. Conference papers, dissertations, and research reports not published in journals. Research with too small a sample size. Articles that do not contain the data or information needed for analysis.

2) Data Sources and Timeframe

The data sources for this study were derived from scientific articles retrieved from the Google Scholar database. Google Scholar was selected due to its extensive coverage of both national and international peer-reviewed scientific publications. The article searches and selection process was conducted between October and November 2025, focusing on publications issued from 2020-2024.

3) Data Collection Techniques

Data collection was conducted through a full-text review of the articles that had passed the initial selection. The restriction on the publication year range adheres to the PRISMA SLR framework, as articles published too recently relative to the search period may potentially lack adequate citation quality and scientific validation (Lusianti et al., 2024). Subsequently, detailed article selection stages were executed sequentially in accordance with the procedure illustrated in Figure 1.

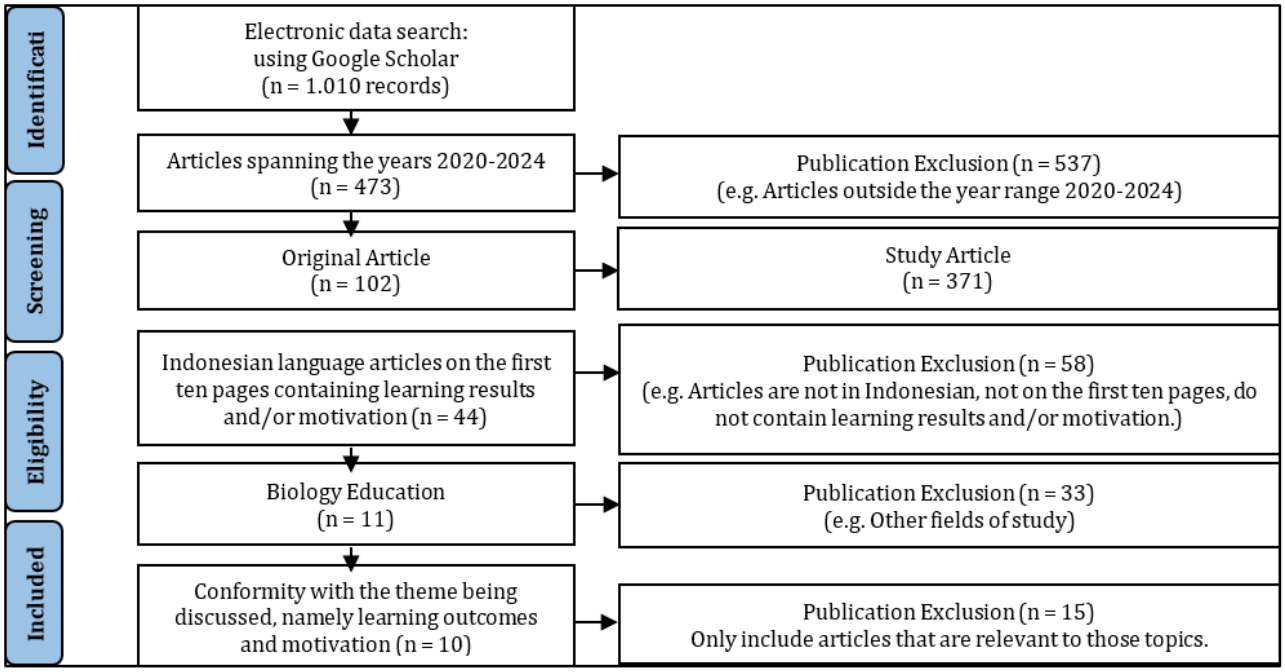

Figure 1 Article selection process in the SLR study using the PRISMA model

4) Data Analysis Methods

Data were analyzed using the Content Analysis technique to identify, organize, and interpret article content based on themes and patterns relevant to the research objectives. Content analysis enables researchers to extract information objectively and in a structured manner through a systematic coding process, thereby ensuring the replicability of the study findings (Ahmed & Diaz, 2022).

Results and Discussion

As shown in Figure 2, the number of relevant research documents demonstrates a significant year-on-year increase over the 2020–2024 period.

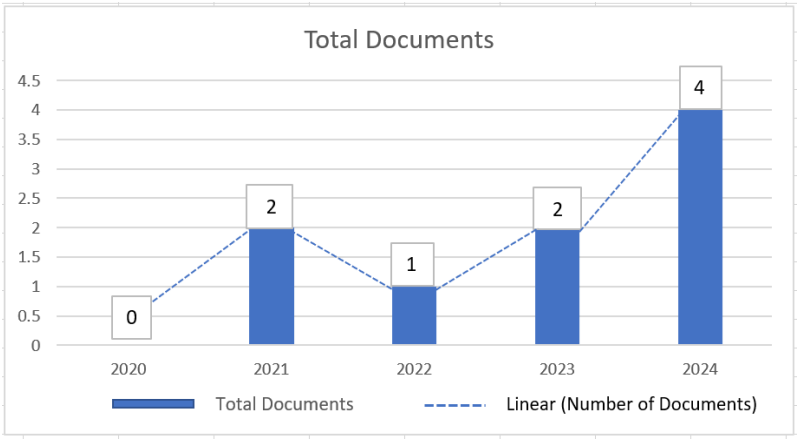

Figure 2 Distribution of the number of research publications on artificial intelligence (AI) from 2020 to 2024

The data presented in Figure 2 demonstrates that the number of relevant research documents experienced a significant year-on-year increase over the 2020–2024 period. This upward trend in publications indicates that the utilization of Artificial Intelligence (AI) in Biology education is gaining growing attention as an innovative strategy to enhance the quality of instruction.

This increase in research volume aligns with the necessity for digital transformation in education, which demands the implementation of adaptive and technology-driven learning. Various studies report that the integration of AI in Biology education facilitates student comprehension of abstract concepts through visualization, content personalization, and the provision of immediate feedback (Faldi et al., 2023; Haidir et al., 2024). These findings reinforce the position of AI as a relevant pedagogical solution for addressing the challenges of Biology instruction in the Society 5.0 era.

The rising trend in AI-related research is also associated with efforts to strengthen the affective domain of learning, particularly student motivation. Several prior studies demonstrate that the utilization of AI-based technology contributes to enhanced learning engagement, self-efficacy, and student interest in actively participating in Biology instruction (Ronsumbre et al., 2023; Zahren et al., 2025). Consequently, the surge in scientific publications reflects an academic awareness regarding the potential of AI to yield positive implications for both student learning outcomes and motivation simultaneously.

The article selection process, utilizing the PRISMA model within the Systematic Literature Review (SLR) framework on 1,010 articles retrieved from Google Scholar, resulted in the final inclusion of 10 articles published in national journals. The synthesis of these 10 articles reveals that the application of AI: including SETS learning media, SUNO AI, chatbots, PlantNet, Google Lens, and Canva yielded significant improvements in student learning outcomes and motivation in Biology education, as summarized in Table 2.

Table 2 Findings of the 10 most relevant articles

Code	Researcher	Problem	Method	Findings
A1	Aina et al. (2021)	Lack of an objective overview regarding biology learning motivation during online learning.	Quantitative, Survey	Student biology learning motivation during online learning was in the "good" criteria (average 71%).
A2	Saputro et al. (2022)	The need to improve students' critical thinking skills.	Quasi-Experiment (Pretest-Posttest Control Group design)	The SETS Learning Model is effective for improving students' critical thinking skills.
A3	Saputra (2021)	The need for alternative media for Distance Learning (PJJ) due to limitations of social media used by teachers.	Descriptive Qualitative, Questionnaire, Observation	The Instagram application is suitable for use as alternative media in Distance Learning (PJJ).
A4	Novitasari et al. (2024)	The emergence of misconceptions in students that must be addressed.	Research and Development (R&D), ADDIE Model	Developing, testing feasibility, and effectiveness of chatbot multimedia to remediate misconceptions (human movement system material).
A5	Octaviani et al. (2024)	The need for high self-efficacy in students to face 21st-century challenges.	Research and Development (R&D)	Aimed to test the validity, practicality, and effectiveness of AI and AR applications to increase self-efficacy.

Code	Researcher	Problem	Method	Findings
A6	Syahlan et al. (2024)	Lack of student and teacher understanding regarding the utilization of Artificial Intelligence (AI) as learning media.	PKM (Community Service) Training with stages: preparation (survey & curriculum drafting), lecture, direct practice, use of AI apps (Gamma, CopyAI, ChatPDF, Smodin, Canva), and pretest-posttest evaluation. Participants: 75 students (Grade XI-XII).	There was a significant increase in student understanding regarding AI. Pretest average score of 72.8 (medium category) increased to a posttest score of 82.9 (high category), resulting in a 10.1% increase. Students were able to implement AI apps to assist with school tasks.
A7	Putri & Yogica (2025)	Testing the influence of music-based learning media (SUNO AI) on students' cognitive learning outcomes.	Quasi-experiment	Aimed to test the influence of SUNO AI as song media on students' cognitive learning outcomes (classification of living things material).
A8	Rahman & Rusdi (2024)	Seeking effective media for plant species identification to improve science learning outcomes.	Quasi-Experiment (Pretest-Posttest Control Group Design)	There is a positive influence from the use of Google Lens media on science learning outcomes in Junior High School (SMP) students.
A9	Mu'minah et al. (2023)	The need for plant identification media that can improve the mastery of learning outcomes.	Experiment, Quantitative	The PlantNet application is effective; 94% of students were declared to have achieved learning mastery.
A10	Muslihat et al. (2023)	The need for teaching materials and maximizing technology to increase science literacy.	Research and Development (R&D), ADDIE Model	Aimed to test the feasibility and effectiveness of an e-module based on Problem Based Learning using Canva media.

Table 2 shows that the use of Artificial Intelligence (AI) in biology learning has experienced significant developments with positive implications for student learning outcomes and motivation (Zahren et al., 2025; Amador & Weston, 2024; Mu et al., 2023). These findings align with various studies that confirm that AI has the potential to support learning through personalization, instant feedback, and adaptive interactions that can increase student engagement in science and biology learning (Okonkwo & Ade-Ibijola, 2021; Huang et al., 2025).

A review of the methodological approaches in the studies summarized in Table 2 reveals a balance between experimental and Research and Development (R&D) approaches. Experimental approaches are used to directly test the implications of AI utilization on learning outcomes and student motivation, while R&D approaches focus on the development and testing of AI-based learning media (Muchtar et al., 2025; Mu et al., 2023). This pattern indicates that AI research in education is oriented not only toward technological innovation but also toward its implications in real-world learning contexts.

The consistent findings in Table 2 demonstrate the contribution of AI to improving learning outcomes and student motivation through various media and learning scenarios. In study (A6), training in the use of AI applications such as Gamma, CopyAI, ChatPDF, Canva, and Smodin was shown to improve learning outcomes, as indicated by an increase in the average posttest score from 72.8 (moderate category) to 82.9 (high category) (Syahlan et al., 2024). Similar findings have also been reported in other studies showing that AI can increase learning engagement, support self-directed learning, and enrich the learning experience through more personalized and adaptive interactions (Haidir et al., 2024; Huang et al., 2025).

Other research findings in Table 2, particularly studies (A5 and A6), show that AI integration correlates with increased self-efficacy and intrinsic motivation in students, which play a crucial role as psychological mechanisms in the successful adoption of AI technology in the classroom (Ronsumbre et al., 2023; Muchtar et al., 2025). Furthermore, research (A10) related to the development of an AI-based Problem-Based Learning (PBL) e-module integrated with Canva demonstrated increased digital literacy and critical thinking skills in students as part of cognitive learning outcomes (Muslihat et al., 2023; Putri & Yogica, 2025).

The cognitive learning outcomes in biology are also reflected in students' critical thinking skills and scientific literacy. These two aspects are integral to higher-level cognitive learning outcomes, reflecting students' ability to understand, apply, and reason scientifically about biology concepts (Usman et al., 2025). The use of AI in learning enables the development of more complex cognitive abilities through concept visualization, data analysis, and problem-based learning.

The impact of AI integration in biology learning is not limited to cognitive aspects but also relates to increasing student learning motivation. AI-based learning media has been reported to increase self-efficacy, learning interest, and

active student engagement in the learning process, thus creating a more meaningful and contextual learning experience (Zahren et al., 2025; Huang et al., 2025).

Overall, the findings in Table 2 confirm that Artificial Intelligence (AI) functions as an active, adaptive, and contextual learning facilitator. Through personalized learning, automated feedback, and support for concept visualization, AI contributes to improving the quality of learning outcomes and student motivation in Biology (Amador & Weston, 2024; Mu et al., 2023). The patterns of AI utilization and impact are further summarized in Figure 3, which illustrates the interrelationships between various aspects of the research findings.

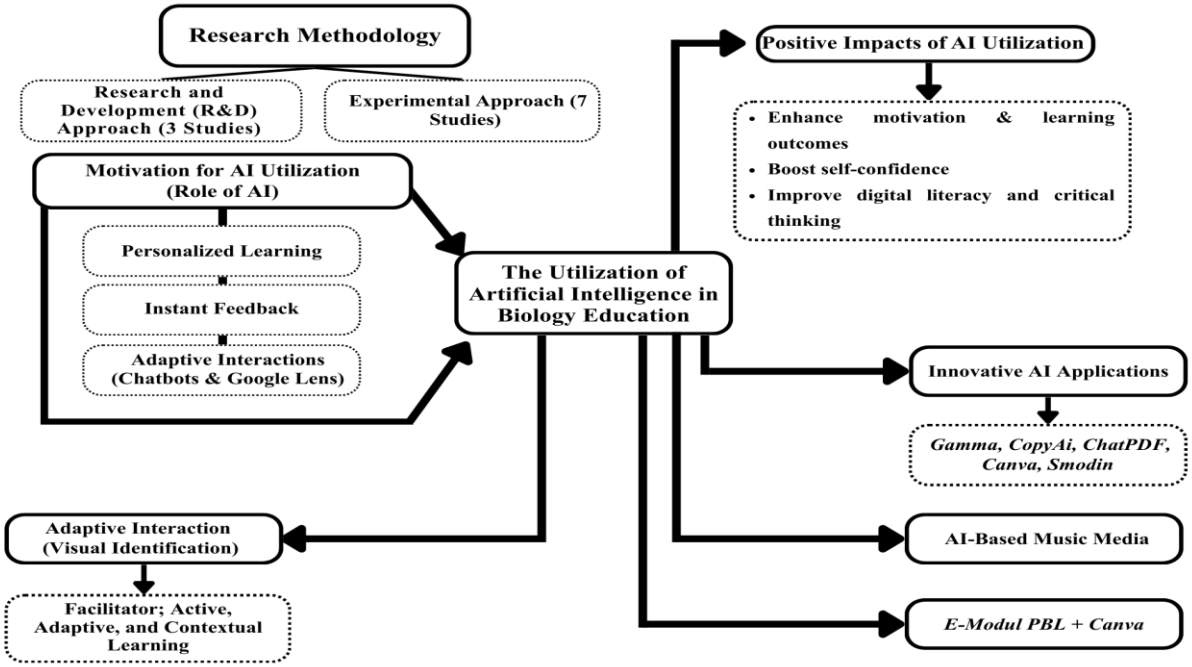

Figure 3 Schematic diagram of artificial intelligence (AI) utilization patterns in biology learning

The diagram in Figure 3 shows that the use of Artificial Intelligence (AI) in Biology learning is built on a strong methodological foundation, dominated by two main approaches: the experimental approach and Research and Development (R&D). The experimental approach is used to empirically test the implications of AI implementation on student learning outcomes and motivation, while the R&D approach focuses on the development and validation of AI-based learning media. This methodological pattern indicates that Artificial Intelligence (AI) research in Biology learning is oriented not only toward technological innovation but also toward its implications in real-world learning contexts (Mu et al., 2023; Muchtar et al., 2025).

The role of Artificial Intelligence (AI) in Biology learning in this scheme is classified into its primary functions of personalized learning and instant feedback. Personalized learning allows for adjustments to the content, pace, and difficulty level of the material to suit the characteristics and needs of students. The instant feedback generated through AI-based systems contributes to increased student engagement and self-efficacy, thereby fostering stronger intrinsic motivation in the learning process (Amador & Weston, 2024; Huang et al., 2025).

The development of digital technology has strengthened the role of AI as a foundation for adaptive learning. AI-based learning systems are capable of analyzing student learning behavior in real time, recognizing interaction patterns, and recommending learning paths tailored to individual needs. This capability enables AI not only to adjust the difficulty level of the material but also to detect the need for timely learning support, thereby contributing to the continuous improvement of student learning outcomes and motivation (Al Fadillah et al., 2024; Okonkwo & Ade-Ibijola, 2021).

The variety of AI application innovations in Biology learning is also clearly mapped in Figure 3, including the use of text, design, visual, and audio tools. Generative applications such as Gamma, CopyAI, ChatPDF, Canva, and Smodin are utilized to support digital literacy and student information processing, while Canva's integration into Problem-Based Learning (PBL) e-modules strengthens material visualization and problem-solving skills. Furthermore, the use of Google Lens as a visual identification tool enables independent and accurate exploration of plant species, thus supporting Biology learning based on discovery and direct observation (Putri & Yogica, 2025).

The auditory aspect of biology learning is also accommodated through the use of AI-based music media, such as SUNO AI. This innovation contributes to bridging the cognitive and affective aspects of learning, particularly in helping

students understand and remember rote biology material, such as the classification and taxonomy of living things. The integration of AI-based audio elements has been reported to increase learning engagement and strengthen concept retention more effectively (Putri & Yogica, 2025; Zahren et al., 2025).

The use of Artificial Intelligence (AI) in biology learning still requires appropriate pedagogical support to avoid hindering the development of higher-order thinking skills. Excessive reliance on AI has the potential to diminish reflection and reasoning processes if students are not properly guided. Therefore, strengthening AI literacy and critical thinking skills is necessary so that AI functions as a learning aid, not a substitute for students' thinking processes (Faizah et al., 2024; Usman et al., 2025).

The overall scheme in Figure 3 emphasizes that Artificial Intelligence (AI) acts as an active, adaptive, and contextual learning facilitator in Biology learning. The resulting positive impacts include improved cognitive learning outcomes, strengthened self-efficacy, and the development of critical thinking and digital literacy skills. Through adaptive interactions and real-time feedback, AI supports a more effective Biology learning process in addressing the complexity of material and the demands of 21st-century education (Amador & Weston, 2024; Mu et al., 2023).

Conclusion

This study concludes that the use of Artificial Intelligence (AI) in Biology learning has positive implications for improving student learning outcomes and motivation. AI acts as an interactive and adaptive learning medium, strengthening the understanding of difficult biology concepts, increasing student engagement, and fostering student self-confidence. Furthermore, AI integration aligns with the needs of 21st-century learning by supporting digital literacy and more active and contextual learning activities. Overall, the analyzed studies demonstrate that AI functions not only as a tool but also as an effective learning facilitator in improving the quality of Biology learning.

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