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Article

Research on the Paths and Practices of Artificial Intelligence Empowering High School Biology Teaching

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Abstract: With the rapid development of artificial intelligence (AI) technologies, their application in education has become increasingly prominent. This study explores the integration of AI into high school biology teaching, aiming to design practical pathways that enhance teaching effectiveness and student learning outcomes. Taking a high school biology lesson on mitosis as a case study, the research demonstrates how AI-driven tools such as dynamic visualization, virtual microscopy, and adaptive assessment can address traditional teaching challenges, promote student engagement, and foster scientific literacy. The study also discusses challenges related to infrastructure, teacher training, and data privacy, proposing feasible countermeasures for sustainable AI integration. The findings provide valuable insights for educators and policymakers seeking to leverage AI to transform biology education at the secondary level.

Keywords: artificial intelligence; high school biology teaching; AI integration; educational technology

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1. Introduction

With the rapid advancement of artificial intelligence (AI) technologies, a new wave of transformation is reshaping basic education. Particularly in subject-based teaching, AI is emerging as a powerful assistant, enhancing the learning process through personalized content delivery and intelligent feedback mechanisms. As a discipline that emphasizes both experimental inquiry and conceptual understanding, high school biology has long faced challenges in improving instructional efficiency and deepening students' comprehension of complex scientific phenomena [1].

In recent years, the integration of AI into educational practice has shown great potential in addressing some of the longstanding difficulties in biology education. Abstract concepts such as DNA replication, protein synthesis, and photosynthesis often prove difficult for students to grasp through traditional lecture-based instruction. Moreover, limitations in laboratory resources and classroom time frequently constrain students' opportunities for hands-on experiments and individualized feedback. These challenges highlight the urgent need for innovative instructional strategies that can enhance visualization, engagement, and personalized learning support [2].

Against this backdrop, the present study aims to explore practical pathways for integrating AI technologies into high school biology teaching. By examining how AI tools can be embedded in key teaching stages—such as lesson planning, classroom delivery, experimental simulation, and formative assessment—this research seeks to propose feasible models that support teaching innovation and learner development. Special focus is given to how AI can empower teachers to optimize instructional design, while simultaneously offering students more adaptive and interactive learning experiences.

This study holds both theoretical and practical significance. Theoretically, it contributes to the growing body of research on AI-assisted instruction in science education. Practically, it provides a reference framework for frontline teachers seeking to incorporate intelligent technologies into their pedagogy. By investigating case-based practices, this paper offers insights into how AI can effectively enhance the teaching and learning of biology in secondary schools, and ultimately promote a more engaging, personalized, and efficient classroom environment.

2. Integration Foundation of Artificial Intelligence and High School Biology Education

2.1. Major Applications of Artificial Intelligence in Education

With the ongoing advancement of artificial intelligence technologies, tools such as natural language processing (NLP), image recognition, intelligent recommendation systems, and virtual or augmented reality (VR/AR) are increasingly being explored in educational settings. These technologies not only improve how instructional content is delivered but also enhance post-class support, personalized learning, and classroom interaction. NLP has begun to show practical applications in intelligent Q&A systems, writing assistance, and automated grading. Image recognition is being gradually introduced in visually intensive subjects like biology and geography. Intelligent recommendation systems are widely used in after-school learning platforms, where they analyze student behavior data to push tailored learning content. Although VR/AR applications remain in the pilot stage, preliminary implementations have emerged in some well-equipped schools. Overall, artificial intelligence offers diversified technological support for education and provides new opportunities for improving the teaching of abstract and experimental disciplines such as high school biology.

Natural language processing, the backbone of AI chatbots and intelligent writing assistants, enables systems to understand, generate, and evaluate human language. In educational contexts, NLP powers automated essay scoring, AI-driven tutoring, real-time translation, and question generation, making it possible to support students in diverse linguistic and cognitive situations. Tools like ChatGPT and other large language models have demonstrated their ability to assist in content explanation, Q&A sessions, and the creation of scaffolded learning materials tailored to student needs.

Image recognition technology, on the other hand, has shown growing potential in subjects requiring visual analysis, such as biology, geography, and physics. In experimental or digital learning platform settings, students can potentially use AI tools to identify plant species, label cell structures in microscope images, or analyze ecological patterns. While still limited in typical classroom practice due to equipment and accuracy constraints, such applications may support deeper understanding through visual engagement and improve accuracy in tasks that traditionally rely on teacher supervision.

Intelligent recommendation systems play a key role in personalized learning. Based on student performance data, learning behaviors, and preference profiles, these systems suggest appropriate learning materials, adaptive quizzes, and revision content. These technologies are more commonly implemented in after-school learning platforms rather than in regular classroom instruction. They help ensure that students receive guidance tailored to their individual learning trajectories.

Virtual reality (VR) and augmented reality (AR) technologies supported by AI have introduced immersive and interactive learning experiences in some pilot or resource-rich environments. Particularly in science education, VR enables students to explore complex biological processes—such as mitosis, cellular respiration, or ecological systems—in a simulated 3D environment. However, widespread implementation remains limited due to hardware costs, infrastructure demands, and time constraints within typical school schedules.

Together, these AI applications provide a powerful technological foundation that, when thoughtfully integrated and supported by infrastructure and teacher training, can enhance instructional design, improve learning outcomes, and support data-informed teaching strategies. In the context of high school biology, where concepts are both abstract and experimentally driven, these technologies hold substantial promise in addressing instructional challenges and creating more engaging, student-centered learning environments [3-5].

2.2. The Core Challenges of High School Biology Instruction

High school biology is a foundational science course that introduces students to the principles of life, from molecular mechanisms to ecosystem dynamics. However, due to its multidisciplinary nature and the complexity of its content, biology instruction at the secondary level presents several pedagogical challenges that impact both teaching effectiveness and student learning outcomes.

One of the primary challenges lies in the abstract nature of biological concepts. Topics such as DNA replication, gene expression, photosynthesis, and cellular respiration involve processes that are microscopic and highly complex. These topics are often difficult for students to visualize or conceptualize through static images or traditional lectures alone. Without sufficient scaffolding or visualization tools, students may struggle to develop accurate mental models, leading to superficial understanding or misconceptions.

A second significant issue is the experimental and inquiry-based nature of biology. Hands-on experiments are essential for helping students internalize theoretical knowledge and develop scientific thinking skills. However, in many high schools—especially in under-resourced or rural regions—there are limitations in terms of laboratory equipment, class size, safety concerns, and instructional time. As a result, students often engage in biology in a passive, textbook-based manner, which diminishes opportunities for scientific exploration and critical thinking.

Moreover, biology classrooms often face heterogeneity in students' cognitive abilities, prior knowledge, and learning motivation. Some students find biological content fascinating and intuitive, while others perceive it as difficult and unengaging, particularly when they cannot relate it to real-life contexts. This divergence in learning styles and interest levels poses a challenge for teachers to maintain inclusive, differentiated instruction in large classes.

Additionally, the increasing volume of curriculum content and pressure to meet exam requirements may lead teachers to prioritize content coverage over deep learning. In such settings, teaching becomes assessment-driven, and there is limited flexibility to explore interdisciplinary connections, current scientific advances, or student-led inquiry projects [6].

Lastly, assessment and feedback mechanisms in traditional biology teaching are often summative and standardized, which makes it difficult to track individual student progress in real time or to offer targeted support. Without timely feedback and formative evaluation tools, students who fall behind may lack the support needed to catch up or stay motivated.

Collectively, these challenges highlight the need for innovative, technology-enhanced instructional approaches. Artificial intelligence, with its capacity for data analysis, personalized content delivery, and multimodal engagement, offers promising solutions to many of these obstacles in high school biology classrooms.

2.3. Feasibility Analysis of Integrating AI into Biology Instruction

The integration of Artificial Intelligence (AI) into high school biology instruction is increasingly feasible due to recent advancements in educational technology, curriculum reforms, and shifting pedagogical paradigms. This section analyzes the feasibility of AI application in biology teaching from three key perspectives: technological readiness, pedagogical alignment, and user adaptability.

1) Technological Readiness

The rapid development of AI-powered educational platforms—such as intelligent tutoring systems, adaptive learning apps, and natural language processing tools—has made it possible to deliver personalized and interactive biology content at scale. Tools like virtual labs, 3D molecular simulations, and AI-driven Q&A systems can provide students with immersive learning experiences that are otherwise difficult to achieve in traditional classrooms.

Moreover, many schools are equipped with basic digital infrastructure, including tablets, computers, and internet access, which lays the groundwork for AI-enabled instruction. The increasing availability of open-access biology datasets and cloud-based AI services further reduces technical barriers for teachers and developers [7].

2) Pedagogical Alignment

AI technologies align well with the pedagogical goals of biology education, which emphasize conceptual understanding, inquiry-based learning, and interdisciplinary integration. Specifically, (1) they facilitate the visualization of abstract concepts through dynamic simulations, enabling students to grasp complex biological processes more intuitively; (2) they support inquiry-based learning by providing real-time data analysis and immediate feedback, which encourages active exploration and timely correction of misconceptions; and (3) they promote interdisciplinary integration by linking biological content with computational thinking, data science, and ethics, thus broadening students' perspectives and highlighting biology's relevance in modern society. These affordances indicate that AI is not a replacement for traditional biology instruction, but a powerful and pedagogically aligned enhancement that reinforces existing teaching methods while introducing innovative ways to engage students and deepen their understanding [8].

3) User Adaptability and Teacher Readiness

Both students and teachers are increasingly familiar with digital tools in the classroom, especially following the acceleration of online and blended learning models in recent years. Students, as digital natives, tend to adapt quickly to AI-driven learning environments and often show high levels of engagement with gamified or interactive platforms.

From the teacher's perspective, while there is an initial learning curve associated with AI tool adoption, many AI applications are designed with user-friendly interfaces and customizable modules. Professional development programs and teaching communities focused on AI-enhanced instruction are also growing, providing support for teachers to integrate AI meaningfully into their lesson plans.

Furthermore, policy support and national education strategies, such as China's "Smart Education" initiative, actively promote AI adoption to modernize teaching and personalize learning, positioning AI integration as both a pedagogical opportunity and a systemic priority [9].

3. Design of AI-Enabled Teaching Pathways in High School Biology

3.1. AI-Supported Lesson Preparation Optimization

Lesson preparation is a critical phase in the teaching process that directly influences the effectiveness of classroom instruction. Traditional biology lesson planning often demands significant time and effort from teachers to design teaching materials, develop exercises, and tailor content to diverse student needs. Artificial intelligence offers powerful solutions to optimize this process by automating routine tasks, enriching instructional resources, and enabling personalized learning design [10].

One prominent AI application in lesson preparation is the use of natural language processing (NLP)-based tools, such as ChatGPT and the iFlyTek AI Teaching Assistant, which assist teachers in generating detailed lesson plans, explanatory notes, and customized question sets. For example, a biology teacher preparing a unit on photosynthesis can input key topics or objectives into the AI platform, which then generates a structured teaching outline, sample explanations, and a variety of practice questions tailored to different difficulty levels. This capability not only reduces the workload but also inspires innovative pedagogical ideas that may otherwise be overlooked.

Furthermore, AI systems can support the creation of personalized pre-study packages that cater to the heterogeneous learning profiles of students. Based on students' previous performance data, AI algorithms can recommend specific reading materials, multimedia content, and interactive exercises designed to address individual knowledge gaps or misconceptions. Such pre-class preparation helps students engage more effectively during lessons and promotes a flipped classroom model where initial knowledge acquisition occurs outside of class time.

In addition to content generation, AI tools facilitate the integration of up-to-date scientific information and educational standards into teaching materials. By continuously accessing vast online databases and recent research outputs, AI can help teachers incorporate the latest biological discoveries, relevant case studies, and real-world applications into their lesson plans, thus enhancing the curriculum's relevance and appeal.

Despite these advantages, it is important for educators to maintain critical oversight over AI-generated content to ensure accuracy, alignment with curriculum standards, and appropriateness for their specific classroom context. Teachers should use AI as a support tool rather than a replacement, combining machine-generated materials with their professional judgment and teaching experience.

In summary, AI-supported lesson preparation not only streamlines the planning process but also enriches the quality and adaptability of teaching resources. This empowers biology teachers to focus more on instructional design and student engagement, ultimately contributing to improved learning outcomes.

3.2. AI-Assisted Interactive Teaching Models in the Classroom

Classroom teaching is the core stage of the instructional process where students actively engage with new knowledge and develop their scientific thinking skills. Artificial intelligence technologies offer diverse interactive modalities that can transform traditional biology classrooms into dynamic, student-centered learning environments.

One significant application of AI in the classroom is through virtual simulation experiments. Biology concepts such as photosynthesis, enzyme activity, and cellular processes often require practical experimentation to deepen understanding. However, limitations in laboratory equipment, time, or safety concerns can restrict hands-on activities. AI-powered virtual labs and simulation platforms overcome these barriers by providing immersive, realistic experiment environments where students can manipulate variables and observe outcomes in real time. For example, platforms like Labster or local cloud-based virtual labs enable students to simulate the effect of light intensity or carbon dioxide concentration on photosynthesis, fostering experiential learning without physical constraints [11].

Image recognition systems also enhance classroom interaction by enabling real-time identification and analysis of biological specimens or microscopic images. Students can use mobile apps equipped with AI to photograph plant leaves, cells, or microorganisms, instantly receiving annotated feedback and explanations. This not only supports observational skills but also encourages inquiry and exploration beyond textbook content.

Moreover, AI-driven intelligent questioning and response systems increase student engagement through personalized, adaptive quizzes and instant feedback. Smart classroom systems can monitor student responses during lectures, identify misconceptions, and adjust question difficulty accordingly. Interactive tools allow teachers to conduct polls, quizzes, and discussions that actively involve all students, making the learning process more inclusive and responsive.

The integration of natural language processing tools enables conversational AI assistants to support classroom dialogue, answer student queries on the spot, and provide hints or elaborations. This reduces the teacher's cognitive load and allows more individualized attention.

By combining these interactive AI modalities, biology teachers can create multifaceted learning experiences that cater to diverse student needs, promote active participation, and enhance conceptual comprehension. Importantly, these technologies complement rather than replace teacher-led instruction, serving as scaffolds to facilitate deeper understanding and critical thinking.

3.3. AI-Driven Personalized After-Class Tutoring

After-class tutoring plays a vital role in consolidating students' knowledge and addressing individual learning difficulties. Artificial intelligence technologies can significantly enhance this phase by providing personalized learning support tailored to each student's unique needs and progress [12].

AI-powered platforms, such as Xuexitong and Yuanfudao, utilize data analytics and machine learning algorithms to analyze students' homework, quiz results, and learning behaviors. Based on this analysis, these systems generate customized practice exercises, review materials, and targeted explanations to help students overcome specific weaknesses. For example, a student struggling with the concept of photosynthesis may receive additional interactive exercises focusing on light-dependent reactions, supported by AI-generated hints and step-by-step solutions.

Furthermore, AI-driven voice assistants and chatbots provide on-demand tutoring support, answering student questions in natural language anytime outside the classroom. This immediate access to assistance fosters autonomous learning and reduces dependence on teachers' limited availability.

Another important feature is the automated generation of error logs and personalized “mistake books”, which help students track and review errors systematically. By reflecting on common mistakes, students can develop metacognitive skills and improve learning strategies.

Additionally, AI platforms often incorporate learning analytics dashboards that present detailed progress reports to both students and teachers. This transparency enables timely interventions and promotes collaborative goal-setting between teachers, students, and parents.

By leveraging AI for personalized after-class tutoring, biology education can better accommodate diverse learner profiles, promote continuous engagement, and ultimately improve academic achievement.

3.4. Data-Driven Intelligent Teaching Evaluation Mechanisms

Effective teaching evaluation is crucial for monitoring student learning progress, identifying areas for improvement, and guiding instructional adjustments. Traditional evaluation methods in high school biology often rely on summative assessments such as exams and quizzes, which provide limited insight into ongoing learning processes. Artificial intelligence offers advanced data-driven solutions that enable more comprehensive, formative, and adaptive evaluation mechanisms.

AI-powered platforms collect and analyze large volumes of student data from various sources, including classroom interactions, homework submissions, quiz results, and virtual lab activities. Through machine learning algorithms, these systems can detect patterns, predict learning outcomes, and identify misconceptions with high accuracy. This continuous data analysis supports formative assessment, allowing teachers to intervene promptly and tailor instruction based on real-time feedback.

One common application is the use of learning analytics dashboards that visually present individual and class-wide performance metrics. Teachers can monitor students' mastery of specific biology concepts, engagement levels, and progress trends, facilitating data-informed decision-making. For example, if many students struggle with understanding photosynthesis, the teacher can adjust lesson plans or provide targeted remedial resources [13].

Moreover, AI-driven adaptive testing systems dynamically adjust question difficulty based on student responses, providing a personalized challenge that maximizes learning efficiency. These systems not only assess knowledge but also evaluate students' higher-order thinking skills, such as analysis and synthesis, which are essential in biology education.

In addition, intelligent evaluation tools can support peer assessment and self-assessment by guiding students through structured reflection and providing automated feedback. This fosters metacognitive awareness and promotes learner autonomy.

Integration with smart campus platforms allows seamless management of evaluation data and supports communication among teachers, students, and parents, enhancing the transparency and accountability of the teaching-learning process.

By harnessing AI-powered data analytics and intelligent evaluation tools, biology educators can move beyond traditional assessment limitations, enabling a more nuanced, responsive, and effective approach to teaching evaluation [14-16].

4. Teaching Practice and Case Analysis

4.1. Case Overview: Mitosis in Eukaryotic Cells

The lesson on "Mitosis" is a core topic in the compulsory high school biology curriculum under the "Molecular and Cellular" module (as outlined in the national curriculum textbook). This lesson focuses on the process of eukaryotic cell division, detailing stages from interphase preparation (DNA replication and protein synthesis) to the mitotic phases—prophase, metaphase, anaphase, and telophase. Students are expected to grasp the dynamics of chromosome behavior and the significance of genetic material distribution during cell division [17].

Given the microscopic and dynamic nature of mitosis, students often struggle to visualize and understand the process through traditional static images and lectures. Therefore, integrating artificial intelligence (AI) technologies to simulate and visualize mitosis offers a promising pathway to deepen comprehension and engagement.

4.2. AI-Enabled Teaching Design and Implementation

The teaching session was conducted in a smart classroom equipped with AI-assisted digital tools, facilitating an interactive and immersive learning experience. However, the effective use of these AI applications depends significantly on the availability of adequate hardware and stable network infrastructure. In environments where such resources are limited, it is recommended to combine AI tools with traditional multimedia resources to ensure all students can benefit.

Key AI applications included:

1) Dynamic Visualization and Animation: AI-powered software presented detailed animations and 3D interactive models of mitotic phases, allowing students to manipulate the timeline and observe chromosome behavior dynamically. While this enhances comprehension, its use requires suitable classroom technology. In settings with limited technical support, integrating conventional visual aids alongside AI animations can help maintain accessibility.
2) Intelligent Interactive Quizzes: An AI-driven classroom response system delivered real-time formative quizzes, adapting question difficulty based on student

responses to provide personalized feedback. Given the possibility of algorithmic misinterpretations, teachers should interpret the AI-generated data critically and adjust instruction accordingly to ensure accuracy and relevance.

3) Virtual Microscopy with AI Assistance: Virtual slide software enhanced by AI image recognition enabled students to explore mitotic structures interactively. Since these tools rely on high-quality imaging and advanced recognition algorithms—and may involve high equipment costs—it is important for teachers to supplement AI tools with clear explanations to support student understanding.
4) AI-Facilitated Classroom Interaction: AI tools monitored group discussions and summarized key points to aid class-wide sharing. However, due to current limitations in AI's semantic understanding, automatic summaries may lack nuance. Therefore, teachers remain the primary facilitators in interpreting and guiding classroom discourse.
5) Personalized Review and Practice: Post-class, an AI learning platform recommended tailored exercises based on in-class performance data. While this personalization supports targeted learning, variability in students' self-management skills means that teacher guidance is essential to help students effectively utilize these resources.

4.3. Teaching Process and AI Integration

The teaching process was systematically designed to incorporate AI tools at key stages to enhance students' understanding and engagement with mitosis. As shown in Table 1, AI-supported activities were embedded throughout the lesson, from preparation to homework, facilitating interactive visualization, formative assessment, and personalized learning.

Table 1. Integration of AI Technologies in Different Teaching Phases of the Mitosis Lesson.

Teaching Phase	AI Application	Description
Preparation	AI-generated lesson plan	Teacher designs content with AI assistance, including animations and quiz banks.
Introduction	Interactive animation	Students watch and manipulate mitosis animations to form initial impressions.
Concept Explanation	Virtual microscopy with AI	Students explore cell images with AI highlighting key structures.
Formative Assessment	Adaptive quizzes via smart system	Real-time quizzes identify misunderstandings; teacher adjusts pace.
Group Discussion	AI-facilitated interaction	AI monitors group responses, summarizes key points for class sharing.
Homework	Personalized AI exercises	Platform pushes exercises tailored to individual student needs.

At the preparation stage, AI-assisted lesson planning helped generate detailed animations and question banks tailored to varying levels of student proficiency. During lesson introduction, students engaged with dynamic animations that allowed them to manipulate mitosis phases and observe chromosome changes in real time, which provided an intuitive grasp of the process.

In the concept explanation phase, virtual microscopy software enhanced by AI image recognition enabled students to explore cell images with highlighted mitotic structures, linking theoretical knowledge with virtual experimental observation.

The lesson incorporated adaptive quizzes delivered via an intelligent classroom response system. This system analyzed students' answers in real time, adjusting question difficulty and providing instant feedback, which supported targeted teaching adjustments.

During group discussions, AI tools monitored interactions, summarized key points, and facilitated class-wide sharing to deepen comprehension. Finally, in the homework stage, personalized exercises recommended by the AI platform reinforced learning outcomes and addressed individual weaknesses. Table 1 summarizes the integration of AI technologies across different teaching phases and their instructional purposes.

4.4. Evaluation of AI-Enhanced Teaching

This case design fully utilizes AI technology to achieve dynamic demonstrations of the cell division process and virtual microscopy observations, enhancing the intuitiveness and interactivity of the teaching content. The application of an intelligent quiz system provides real-time knowledge assessment during class, which helps promote personalized learning and instructional adjustments. In the teaching design process, attention should be paid to the dependency of AI tools on hardware and network environments, as well as the reasonable arrangement of interactive sessions and traditional lecturing time, to ensure that students can both experience intuitive learning content and systematically grasp core knowledge. Future teaching can further integrate diversified AI-assisted functions to improve the intelligence and personalization of teaching resources, thereby continuously optimizing teaching effectiveness. Additionally, professional development and technical training for teachers are important guarantees for the deep integration of AI and teaching. Through continuous optimization of teaching design and technology application, more effective and efficient solutions are expected for the instruction of complex biological knowledge [18].

5. Challenges and Countermeasures

5.1. Challenges in AI-Enabled High School Biology Teaching

Although artificial intelligence holds great promise for enhancing biology education, its integration into high school teaching still encounters multiple challenges. One significant obstacle is the uneven technical infrastructure across schools, especially in underdeveloped regions where reliable high-speed internet, smart devices, and technical maintenance support are often lacking, thereby limiting the deployment and effectiveness of AI tools. Moreover, many teachers have limited experience or confidence in applying AI technologies in the classroom, which can lead to underutilization or incorrect use of these tools [19].

In addition, disparities in students' digital literacy and access to devices create inequities in learning opportunities, as not all students can equally benefit from AI-assisted instruction. The alignment of AI content with localized curricula also presents difficulties; many AI resources are designed with broad applicability in mind and may not fully correspond to specific teaching standards or cultural contexts, which reduces their practical relevance. Finally, the collection and use of student data by AI platforms raise important concerns related to privacy protection and ethical management, necessitating careful consideration in educational applications.

5.2. Countermeasures and Recommendations

To effectively address the challenges encountered in AI-enabled high school biology teaching, a comprehensive, multi-faceted approach is necessary. Firstly, educational authorities and schools should prioritize investment in digital infrastructure, particularly in rural and under-resourced areas, ensuring reliable high-speed internet, smart classroom devices, and maintenance services. Establishing dedicated technical support teams is essential to guarantee the smooth operation of AI tools. Equally important is the enhancement of teacher training through systematic professional development programs that focus on AI literacy, pedagogical integration, and troubleshooting. Teachers should be encouraged to participate in workshops, online courses, and peer collaboration platforms, while receiving ongoing technical assistance during teaching to build confidence and competence.

To promote equity, schools need to implement device lending programs or provide subsidies to ensure all students have access to necessary technology. Curriculum designers must consider variations in students' digital skills by offering scaffolded AI-based learning activities tailored to different proficiency levels. Collaboration between developers and educators is crucial for creating AI applications and content aligned with local curricula and student backgrounds, with continuous feedback mechanisms to refine these resources and enhance classroom relevance [20,21].

Furthermore, establishing robust data privacy and ethical frameworks is vital. Clear policies should be formulated on how student data is collected, stored, and used within AI platforms. Training educators on data protection and raising awareness among students and parents will foster trust and ensure compliance with national regulations and ethical standards. In terms of instructional methods, blended teaching approaches that combine AI-enabled activities with traditional methods are recommended to balance technological benefits with human interaction and critical thinking development, thereby preventing over-reliance on technology.

Finally, engaging parents, local education authorities, and technology providers is essential for creating a collaborative ecosystem that supports AI integration, sustains innovation, and addresses practical challenges. By implementing these multi-dimensional strategies, high school biology education can better harness the potential of AI to enhance teaching quality, student engagement, and learning effectiveness.

6. Conclusion

This study explored the integration of artificial intelligence in high school biology teaching, focusing on the design and implementation of AI-enabled instructional pathways through the case of mitosis. The findings demonstrate that AI technologies, such as dynamic visualization, virtual microscopy, and adaptive assessment, can effectively address traditional teaching challenges by enhancing students' conceptual understanding, engagement, and scientific skills.

Despite existing technical, pedagogical, and ethical challenges, targeted countermeasures including infrastructure enhancement, teacher training, curriculum alignment, and data governance can promote sustainable and equitable AI adoption in biology education.

Looking forward, continued interdisciplinary collaboration among educators, technologists, and policymakers is essential to further refine AI tools tailored to diverse learning contexts. Future research may focus on longitudinal studies of AI's impact on student outcomes and exploring more accessible, context-sensitive AI applications for varied educational settings.

In conclusion, AI holds significant potential to enhance high school biology teaching by fostering deeper learning and preparing students for future scientific challenges.

References

1. W. Holmes, M. Bialik, and C. Fadel, *Artificial intelligence in education: Promises and implications for teaching and learning*. Center for Curriculum Redesign, 2019. ISBN: 9781794293700.
2. D. M. Heeg and L. Avraamidou, "The use of Artificial intelligence in school science: a systematic literature review," *Educ. Media Int.*, vol. 60, no. 2, pp. 125–150, 2023, doi: 10.1080/09523987.2023.2264990.
3. S. Zha et al., "A Case Study of Integrating AI Literacy Education in a Biology Class," *Int. J. Artif. Intell. Educ.*, 2025, pp. 1–25, doi: 10.1007/s40593-025-00476-8.
4. N. S. M. Al-Muqbil, "The Impact of an Artificial Intelligence Application-Based Training Program on Developing Sustainable Thinking among High School Biology Teachers," Educ. Sci.: Theory Pract., vol. 24, no. 1, 2024, doi: 10.12738/jestp.2024.1.016
5. L. Shi, A.-C. Ding, and I. Choi, "Investigating teachers' use of an AI-enabled system and their perceptions of AI integration in science classrooms: A case study," *Educ. Sci.*, vol. 14, no. 11, p. 1187, 2024, doi: 10.3390/educsci14111187.

6. M. Usak, "Artificial intelligence in biology education," *J. Balt. Sci. Educ.*, vol. 23, no. 5, pp. 806–808, 2024, doi: 10.33225/jbse/24.23.806.
7. G. Mercan and P. S. Z. V. Selçuk, "Revolutionizing biology education through artificial intelligence: Pedagogical strategies, innovations, and ethical frameworks," in *Studies on Social and Education Sciences 2024*, S. Jackowicz and O. U. Kus, Eds. Monument, CO, USA: ISTES, 2024, pp. 112–131. ISBN: 9781952092695.
8. B. Liu et al., "Exploring the application potential of generative artificial intelligence in high school geography teaching: Scenarios, limitations, and improvement strategies," *J. Educ. Res.*, 2025, pp. 1–14, doi: 10.1080/00220671.2025.2510396.
9. V. Shakori Moghadam, "The role of artificial intelligence in biology teaching," *Sexual Psychol. Disord.*, vol. 1, no. 4, 2024.
10. A. Yoo, "Artificial intelligence in classrooms: How artificial intelligence can aid in teaching biology," in *A Biologist's Guide to Artificial Intelligence*, Academic Press, 2024, pp. 287–300, doi: 10.1016/B978-0-443-24001-0.00017-8.
11. D. T. K. Ng et al., "A review of AI teaching and learning from 2000 to 2020," *Educ. Inf. Technol.*, vol. 28, no. 7, pp. 8445–8501, 2023, doi: 10.1007/s10639-022-11491-w.
12. O. A. Taiwo, K. A. Omotayo, and O. J. Onifade, "Artificial intelligence assisted instructional strategy and students' attitude towards learning of biology in senior secondary schools in Oyo state," *J. Niger. Inquiry Humanit.*, no. 56.
13. C. T. Tchakoua et al., "Leveraging artificial intelligence and interactive learning approaches for enhanced student achievement and perspectives in a biology course," *Int. J. Sci. Acad. Res.*, vol. 4, pp. 6708–6712, 2023.
14. A. Prnjak et al., "Using simulation in teaching artificial intelligence," *INTED2023 Proc.*, IATED, 2023, doi: 10.21125/inted.2023.1886.
15. A. A. Anand Selvam, "Exploring the impact of artificial intelligence on transforming physics, chemistry, and biology education," *J. Sci. Impact*, 2024, doi: 10.21428/a70c814c.747297aa.
16. F. Pedro et al., "Artificial intelligence in education: Challenges and opportunities for sustainable development," 2019.
17. C. Papaneophytou and S. A. Nicolaou, "Promoting Critical Thinking in Biological Sciences in the Era of Artificial Intelligence: The Role of Higher Education," *Trends High. Educ.*, vol. 4, no. 2, pp. 24, 2025, doi: 10.3390/higheredu4020024.
18. N. Akhtar, R. Matloob, and R. Nawaz, "Exploring The Impact of Artificial Intelligence in Teaching of Biology at Secondary Level," *Int. Res. J. Manag. Soc. Sci.*, vol. 5, no. 3, pp. 427–440, 2024.
19. M. Hao, Y. Wang, and J. Peng, "Empirical research on AI technology-supported precision teaching in high school science subjects," *Appl. Sci.*, vol. 14, no. 17, p. 7544, 2024, doi: 10.3390/app14177544.
20. I. Aripin et al., "Artificial intelligence in biology and learning biology: A literature review," *J. Mangifera Edu.*, vol. 8, no. 2, pp. 41–48, 2024, doi: 10.31943/mangiferaedu.v8i2.185.
21. L. Dong, X. Tang, and X. Wang, "Examining the effect of artificial intelligence in relation to students' academic achievement in classroom: A meta-analysis," *Comput. Educ. Artif. Intell.*, 2025, p. 100400, doi: 10.1016/j.caeai.2025.100400.