Exploring The Impact of Artificial Intelligence in Teaching of Biology at Secondary Level

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Abstract

AI is already causing changes across various aspects of the education system including instruction delivery, student evaluation or assessment, and management. The organisation also actively participates in the advancement of science learning. This systematic review aims to provide a priori interpretation of the empirical research relationship between AI and science education. This study provides a synthesis of the current state of research on the effectiveness of AI interventions on learner outcomes, the contexts in which AI has been introduced in science education, and the experiences and perceptions of students and teachers on AI use at school, and the difficulties of using AI in these contexts. Thus, 74 records were included in the present systematic analysis. The study showed that, to obtain different educational and instructional outcomes in science, the teacher uses AI tools and applications. The conclusion that was arrived at from this paper has implications for teachers, education administrators as well as policy makers. Education is a fast growing and developing field whose ongoing change is influenced by technological growth, especially AI. In the context of secondary education, biology poses certain difficulties, for instance, how to explain cell biology, genetics, structures of different types of ecological interconnections. The potential of using AI in the teaching of biology is what this study aims to unearth through effective use of technology where it can be applied to provide customized learning experiences, tests and quizzes and even simulators. In that regard, the study seeks to compare the current teaching and learning models that rely on the application of AI with the conventional modes of learning and teaching with the intention of comparing the amount of interest and understanding displayed by learners, as well as the levels of performance. Based on research findings, the work will advance the existing discussion on the application of AI in STEM education and present practical recommendations for educators,

policymakers, and technology stakeholders. This paper pursues the research question of occasions that led to the usage of artificial intelligence. In implementing the instructional management and learning process in secondary education of model college Islamabad. It examines educational impacts of new technologies on how students learn and how institutions instruct and change. New technological innovations and the progressive peregrinator have called for Improved and more effective ways of determining performance. To analyse the future or future nature of higher education with special reference to artificial intelligence system in our colleges. We identify some directions for further research as we look at several of the challenges for institutions of secondary education and student learning in the adoption of these technologies for teaching, learning, student support and administration.

Keywords AI - Artificial intelligence, Science education, Machine learning, Science learning

Introduction

1.Background

Education has always adapted to technological advancements, from the chalkboard to digital classrooms. Artificial intelligence (AI) represents the next frontier, with its ability to provide personalized, data-driven, and adaptive learning experiences. In the context of biology, a subject rich in conceptual and practical learning, AI has the potential to address challenges such as varying student comprehension levels, limited access to laboratory resources, and the need for individualized instruction.

Secondary school students often find biology topics like genetics, cell structures, and ecological dynamics abstract and difficult to grasp (Singh et al., 2020). AI tools such as intelligent tutoring systems, virtual labs, and adaptive testing can create an engaging and effective learning environment. Despite its potential, the application of AI in secondary education remains underexplored, particularly in biology teaching.

2. Rationale for the Study

The traditional teaching methods in biology, such as lectures and textbook-based learning, often fail to meet the diverse needs of students (Ashraf, Muztagh, & Salami, 2014). Interactive AI-driven platforms can simulate complex biological processes, provide instant feedback, and adapt to individual learning paces. This research investigates whether incorporating AI tools into secondary-level biology teaching improves student outcomes compared to conventional methods.

3. Problem Statement

Despite growing interest in AI-enhanced education, its implementation in secondary schools faces challenges such as limited awareness, teacher training, and infrastructure (Brown & Robinson, 2021). Furthermore, empirical studies focusing on the effectiveness of AI in specific subjects like biology are scarce. This study seeks to address this gap by exploring how AI can enhance teaching and learning in biology classrooms. The integration of artificial intelligence (AI) in education has transformed the traditional learning environment, offering new opportunities for interactive and personalized instruction. In the context of biology education, AI tools can simulate complex biological processes, foster inquiry-based learning,

and enhance student understanding. However, the extent of AI's effectiveness in improving learning outcomes at the secondary level remains underexplored. This study aims to bridge this gap by examining the role of AI in biology teaching and its impact on students' academic performance and engagement.

Overview of Science Education in the teaching learning process

It is argued that the rationale of science is multifaceted does not only seek to voice out and pass knowledge, but also to empower the public capable of rational and utilitarian course in the use of science (Almasri, 2021; Grinnell, 2021). This is inline with the "Science for All" program which pays especial concern on equiping all students irrespective of the fields they intend to venture into as good scientific citizens (Almasri et al., 2022; Mansour, 2009). Science education therefore involves the acquisition of scientific knowledge in terms of the ability of science to provide a framework for the reasoning of student scientific understanding through the teaching and learning of scientific theories, processes and experiments (Alharbi et al., 2022; Liu & Pásztor, 2022; Mogea, 2022b; Zulyusri et al., 2023).Thus it involves the nature of science education from knowledge Hewapathirana & Almasri (2022); Kola (2013) have opined that national development is highly conditioned on scientific inputs to afford powerful hints as to the pathway of the economic development of a country alongside the advancement and enhancement of the advancement of the entire nation. The need for improvement of educational approaches and their alignment with the demands of the 21st century is an encouraging call in the "Call to Action" for science education (Holme, 2021, Ibáñez & Delgado-Kloos, 2018). For the construction of students' preliminary knowledge and to maintain their interest and course readiness for STEM professions in compliance with the demand in the contemporary world, it is imperative. By focusing on learner experience, the use of artificial intelligence gives the science education the fun and easy to understand outlook for student of all level and achievers.

Is It Possible to Introduce AI into the Learning Process of Science?

As AI technology is advancing and popularized, there are vast potential for AI to be applied in science education but there are also significant barriers. Until now, AI already has an immense potential of changing how science is taught and learned. Possibly one of the most effective uses of AI in science education is that of using artificial intelligence to mimic scientific experimentations hence offering simulation laboratory stations to science learners. This means that students can practice and make significant changes in their scientific skills in the safety of a computer simulation, thus possibly minimize costs and open up new ways of teaching/learning scientific concepts that would otherwise not be possible physically in a laboratory (Wahyono et al., 2019). However, such modes of interaction can be lacking or limited in the richness of touch, especially the connection with the real environment , which distinguishes certain forms of learning (Tang & Cooper ,2024).

AI also aids educators in delivering a better learning experience that is not limited to a common mass Education System and instead ensures an incidences for students. Not only can artificial intelligence recommend and assess work, but it can also determine patterns of students' learning and adapt with great precision to individual students (Zhai et al., 2021; Zhai et al., 2020a, b). Nevertheless, the success of those personalised learning systems

strongly depends on the data the system was trained on and may contain bias and perpetuate existing disadvantages.Moreover, item level feedback and course learning paths can be important for students to overcome misunderstanding or lack of understanding the phenomena from the physical world (Mavroudi et al., 2018). To the science educators also, AI has the merit of enhancing the management of the students' performance by frequent monitoring and interventions as and when necessary. However, night can make the education, especially the compulsory science education, interesting to students, including students with learning difficulties, by applying the technology of AI in the creation of inter- active and immersive classrooms. In future as the AI technology develops more prospectively there is possibility to turn into the member and allied in science learning that extends ways to enrich and enhance the learning opportunities of students across all levels.Anticipated Benefits of AI Implementation in Science Teaching

AI integration in the education system has a variety of advantages to science education, as it transforms teaching and learning activities for science. It is possible to develop an AI that can watch how the students learn and adapt the content depending on the students, abilities or ways in which they learn. It becomes easier and faster for students to understand lessons through these styles of developing resources for education. It allows them to do so in their own time and at a pace that they understand will suffice their learning style (Zawacki-Richter et al., 2019). Similarly, through application of AI Massive data analysis in science, teachers teaching science subjects can be in a position to tell how their students are faring in those subject areas that may require special attention.
Another benefit is the promotion of exploratory learning using virtual labs and reenactment. Furthermore, applying AI in testing, one can implement complex reasonable tests that for one or another reason would be unproductive or unreasonable to perform in class. Such virtual tasks offer combinatorial learning experience interactions and in such virtual settings, learners get"–exposure to various conditions; this presents them with a better understanding of a particular scientific premise (Ibáñez, Pallesen, Smákurð, Kristjánsson, & Ómarsson, 2018). This approach was not as supporting to extending understudy engagement as it would have been otherwise beneficial to offer an escalated understudy even more proficient access to quality science teachings. F Akai lifestyle products offer chances for inter-faculty understudies and teachers to be in an able to inter-change logical thought and indeed be able to comprise an international viewpoint toward logical issues. Such interconnection also makes it possible to introduce into lessons diverging programs, so under-studies come across real problems and datasets in the field of logic (Holmes et al., 2023).

Ethical Challenges of Artificial Intelligence in Education

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Objectives of the Study.

1) an attempt to identify what distinguishes traditional ways of teaching from the ones using AI in teaching biology.
2) To determine the extent to which the use of artificial intelligence will enhance the learning achievements of students in biology lessons.
3) To evaluate the views of teachers and students on incorporation the AI in biology learning and teaching processes'

Research Questions

(1) Contexts of AI Adoption: To what extent are there differences of the potentials of the delivery and adoption of the AI tools within the science education sectors by adopting countries level, subjects and levels of education.
(2) Student and Teacher Perceptions: The study poses the following research questions: What perceptions and attitudes do the students and teachers harbor towards the employ of artificial intelligence tools in teaching and learning of science content?

Statement of the Problem

Biology – as the science of life – can perhaps benefit to a limited extend from the application of AI.
As it was expected, there are few applications of AI technologies in teaching biology at the secondary level even though their value has been known.

Insufficient Studies on How AI is affecting Education

Currently, the extent to which teaching and learning of biology at the secondary level has been enhanced by AI is not well researched.

Handicap of Teacher Training

Experience has shown that many biology teachers do not know how to and are not trained to include the AI tools in their teaching practices.

AI resources for different individuals

On this basis, the application of AI tools and technologies in learning processes leads to inequality between schools and regions among students.

Challenges and Barriers to AI Integration:

- Learning needs not well suited to AIrientation On the same note, since AI is created to advance personalization, it may not capture the diverse learning needs encompassing a

standard plurality of adopters' competency level.

- The Technological Readiness Model suggested that resistance to technological change arises from a lack of assessment of adequate technological readiness.
- AI is rejected by teachers and school systems since they are unfamiliar with the relevant technologies, want to protect their jobs, or due to expected difficulties in the implementation of such solutions.

High Cost of Implementation

Some schools are put off by the costs of implementing AI tools and structures into the secondary education system.

Risk Too Much Reliance On Technology

Large scale utilization of the model may also lead to the limitation of physical handling of biological models and interaction between the teacher and the students.

Ethical and Privacy Concerns

Some issues will therefore arise touching on data privacy particularly with regard to the type of information that is being collected and processed by AI in education.

Lack of Curriculum Alignment

As it stands, there may be many plans, syllabi or programmes of studies in biology classrooms that may not align with the use of AI tools and therefore any attempt to integrate the tools will almost entirely destabilise the conventional teaching plans and assessments that educators have in place.

Significance of the Study

Enhancing Teaching Methodologies

AI offers innovative tools such as virtual labs, simulations, and adaptive learning systems, which can make biology concepts more accessible and engaging for secondary school students.

Improved Student Understanding

By using AI for personalized learning, students can receive tailored instruction that aligns with their learning pace and style, addressing individual needs effectively.

Promoting STEM Education

Integrating AI in biology can inspire students to explore STEM fields by showcasing real-world applications of biology concepts.

Developing Critical Thinking Skills

AI-driven problem-solving tasks can foster critical thinking and analytical skills by engaging students in interactive and inquiry-based learning.

Supporting Teachers
AI can assist educators by automating administrative tasks, such as grading and lesson planning, allowing them to focus on student engagement and teaching quality.

Bridge Learning Gaps
AI systems can identify gaps in student understanding through assessments and provide targeted resources to address these deficiencies.

Inclusivity in Education
AI-powered tools can support students with diverse abilities, including those with learning disabilities, by providing accessible and adaptive content.

Data-Driven Insights
AI can collect and analyze data to offer actionable insights for teachers and administrators, helping to refine instructional strategies and curriculum design.

Preparing Students for Future Challenges
Familiarizing students with AI technologies in their biology education equips them with skills and knowledge critical for the 21st-century workforce.

Encouraging Lifelong Learning
By creating an interactive and engaging learning environment, AI can inspire students to develop a lifelong interest in biology and science-related fields.

Literature Review
AI implementation in learning has been discussed across myriad disciplines within STEM education. A review of relevant studies provides the following insights:

AI in STEM Education:
According to Ashraf, Muztagh, and Salami, (2014), in the same vein, assert that critical thinking and problem-solving skills on STEM related subjects has been boosted by AI. The kind of learning portrayed in the study has highlighted how AI might improve interaction and individualization.

Adaptive Learning Systems:
Brown and Robinson (2021) highlighted the instances when adaptive systems powered by AI analyses help the teacher to identify each learner's preferences and dislikes, pitch plans, and give immediate feedback. They mentioned effective results in the level of participation and the level of board retention.

Biology-Specific Applications:
Singh et al., (2020) have focused on analysing use of virtual labs and simulations in teaching biology, with focus that in the context of pandemic they are capable to fill gaps in practical learning. But they said that more focused studies needed to be carried out on this level of

education particularly at the secondary level.

Teacher and Student Perceptions:
Wilson & Carter (2019) signal that the students are receptive to AI technologies because of the interactions they offer while the teachers saw the training and implementation cost as a weakness.

Challenges in AI Implementation:
Rajan and Gupta (2018) identified barriers such as insufficient infrastructure, deficiency and lack of knowledge about artificial intelligence of teacher training and refresh of course and not aware up-to-date knowledge about the subject, and resistance to change as significant obstacles integrating AI into classrooms in teaching learning process

Theoretical Framework
This study is grounded in constructivist learning theory, which posits that learners construct knowledge through active engagement. AI tools align with this approach by providing interactive and hands-on learning experiences.

Scope and Limitations
The study focuses on secondary school biology classes in urban schools with access to AI tools. While the findings may provide valuable insights, they may not fully generalize to rural or under-resourced schools.

Methodological Overview
The research employs a quasi-experimental design with pre-test and post-test assessments to measure the impact of AI tools. Surveys and interviews will gather qualitative data on teacher and student perceptions.

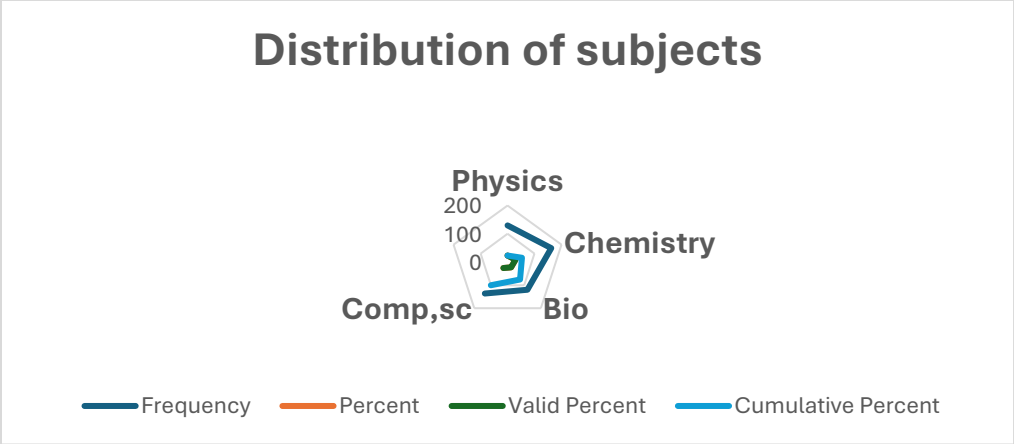
Methodology
Research Design
A quasi-experimental design with pre-test and post-test assessments was used to evaluate the impact of AI-based teaching tools.

Sample
The sample included 547 secondary school students from five MODEL COLLEGES, selected through stratified random sampling to ensure diversity in demographic and academic backgrounds.

Distribution of subjects
Phy, Chem. Bio. Computer science

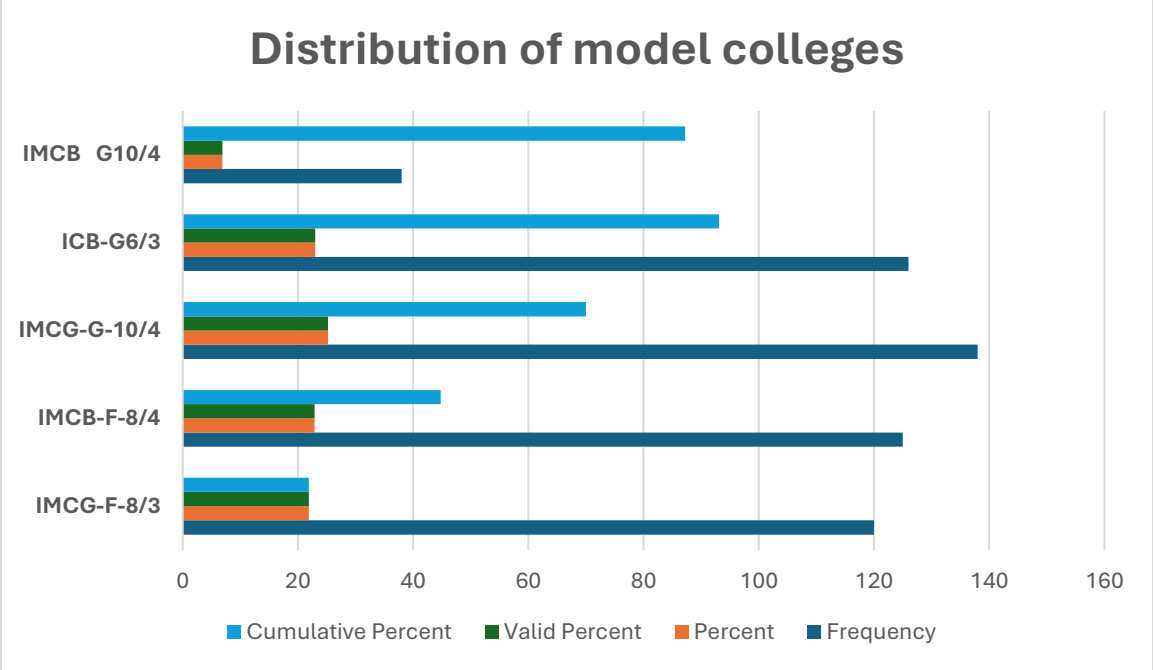
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	**Physics**	130	23.8	23.8	23.8
	Chemistry	162	29.6	29.6	53.4

	Biology	119	21.8	21.8	75.1
	Computer Science	136	24.9	24.9	100.0



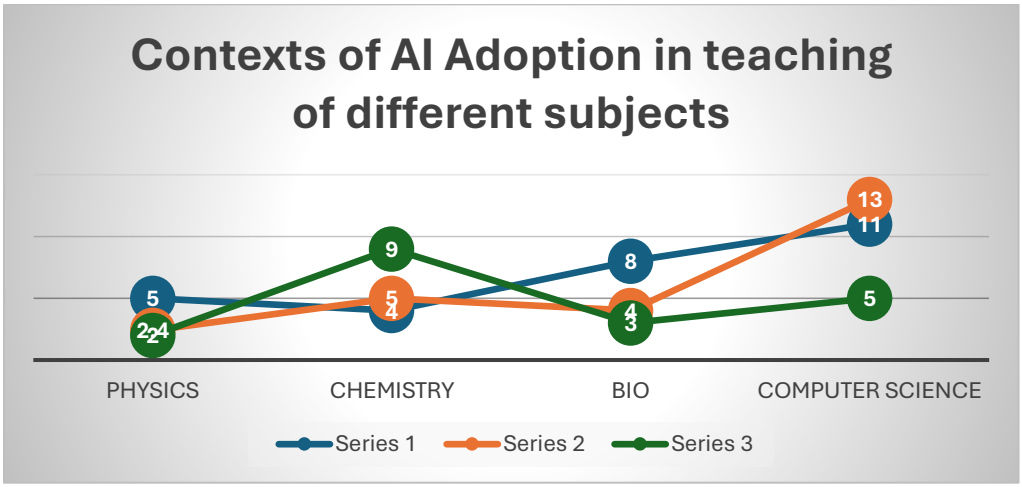
Distribution of Model Colleges

IMCG; F-8/3 IMCB, F-8/4 IMCG, G-10/4 ICB,6/3, IMCB,G10/4				
	Frequency	Percent	Valid Percent	Cumulative Percent
IMCG; F-8/3	120	21.9	21.9	21.9
IMCB, F-8/4	125	22.9	22.9	44.8
IMCG, G-10/4	138	25.2	25.2	70.0
ICB, G-6/3	126	23.0	23.0	93.1
IMCB, G10/4	38	6.9	6.9	87.2
Total	547	100.0	100.0	



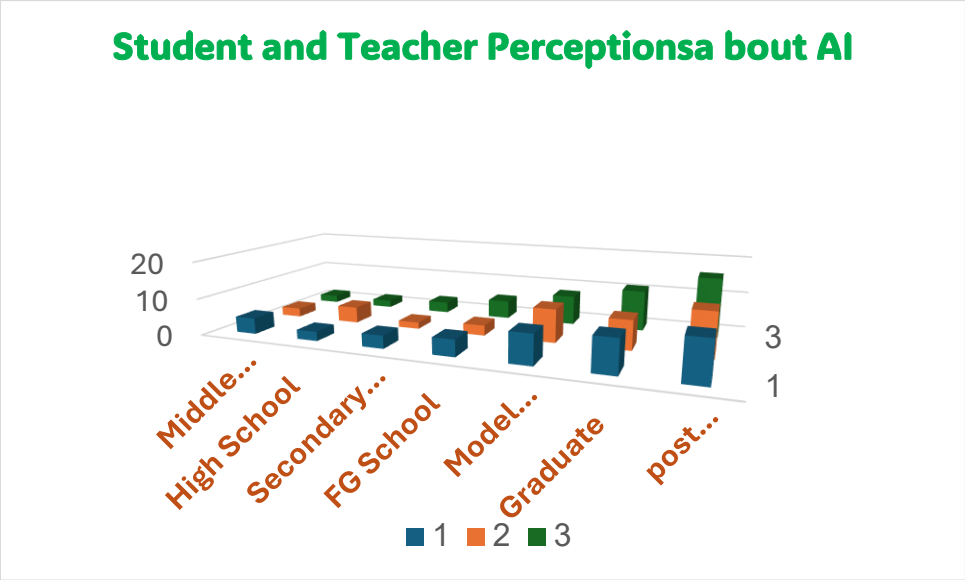
: Contexts of AI Adoption in teaching of different subjects

To assess the feasibility to examine the ideas of AI tool application in science education as unbalanced across countries, levels, subjects. This paper established that artificial intelligence integration has been implemented across various contents taught under science education subjects including; Physics, Chemistry, Biology and Computer science. The reviewed studies were extremely overrepresented by general investigations that did not define any domain of science (n = 21, 28.39 %),The second- smallest field was the subject of computer sciences, which contributed to 11 papers, 14.60%. Lists were then continued by Biology with nine (n = 10, 15.19%); and eight (n = 8, 10, 81%) papers.



Student and Teacher Perceptions

Aimed at investigating the perceived synthesis of AI science teachers and students. The presented research provided complex approaches to the integration of AI in scientific learning among learners and educators. Possible AI tools as an extension of the learning experiences received students' attention. Students demonstrated improvements in interest and subject knowledge through use of AI-based interventions suggesting positive attitudes to AI for learning usefulness Students from all levels of education



Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Male and Female	1.4879	535	.50032	.02163
	Phy,chem.Bio.Comp,sc	2.4542	535	1.10042	.04758

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Male And Female & phyics,chemistry .Biology .Comp,Sc	535	.151	.000

outcomes (Ferrarelli & Iocchi, 2021; Ledesma & García, 2017). For example, Bitzenbauer (2023) conducted a study that predicated that using ChatGPT in Physics classroom positively impacted of students' perception in Germany. Similar to this, for undergraduate students in the United States, Avelino et al. (2017) also highlighted the same.

Such sources revealed that students were more interested in the various science classes when AI was being incorporated in learning practices. Students especially appreciated the abilities of using prediction and giving feedback to the learner themselves (Azcona et al., 2019).This study suggested that science students using AI-based tools as enjoyable and useful teaching learning resources and activities for students Most of the student has willingness about these

tools in the future and some in the existing circumstance particularly in classroom according to Elkhodr et al. (2023).the United States.

Students reported their increased interest in different science courses when AI was integrated into the learning environments. Students particularly admired the AI's power to provide prediction and personalized feedback (Azcona et al., 2019). According to Elkhodr et al. (2023), science students perceive AI-based tools as useful and enjoyable teaching learning resources and activities while most students showed a willingness to use them in the future and someone in existing situation especially in the classroom.

Instruments Instruments:

- Pre-test and post-test questionnaires to measure academic performance.

Data Analysis

Quantitative data were analyzed using statistical tools (e.g., paired t-tests, ANOVA) to compare pre-test and post-test scores.

Conclusion

The integration of AI in teaching biology at the secondary level demonstrates significant potential to enhance learning outcomes and engagement. The findings highlight the need for professional development programs to equip teachers with AI skills and for schools to invest in technology infrastructure.

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