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AI-Based Assessment Systems and Their Effect on Biology Academic Performance

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Abstract

Introduction of Artificial Intelligence (AI) into the educational assessment system is changing the teaching and learning process, in particular sciences. The study focuses on the impacts of AI assessment tools on the quality of feedback, motivation, engagement, and conceptual understanding of biology learners based on the constructivist and data-driven learning theories. The mixed-method design allowed the research to apply both quantitative and qualitative approaches to the study to provide a holistic description of the impact of AI on learning outcomes. Quantitative data were collected in a sample population of 320 biology students in the secondary level by using achievement scores on pre-test and post-test and perceptions were collected with the help of a structured Likert-scale questionnaire. Qualitative information on the topic of using AI assessment systems was gathered, and it was represented by semi-structured interviews with biology teachers, who utilized the following AI assessment systems: Grade scope, Century Tech, and Google Classroom AI analytics. Data was analyzed using descriptive statistics, t-tests, ANOVA, and multiple regression analysis to determine the connection between AI assessment and performance indicators. The results revealed a statistically significant improvement in the academic health and motivation of the students after exposure to AI-based formative assessment. It is suggested to introduce AI evaluation tools into the curriculum design, educate teachers on AI analytics, and render the use of AI ethical and fair.

Keywords: Artificial Intelligence, formative assessment, biology education, academic performance, feedback analytics, learning engagement, adaptive learning systems, educational technology.

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Introduction

Personalized learning is one of the most prominent impacts of AI-based assessment systems on the academic performance of the field of biology. AI systems will examine the answers of students, their learning habits, and performances to determine the personal strengths and weaknesses. According to this analysis, it is possible to customize assessments to learners and their level of cognitive abilities and needs of learning (Adelana et al., 2024).. As an example, students who have difficulties in learning about genetics, cell division, or ecological cycles can be shown specific quizzes, feedback, and remedial tasks, and those who are more advanced are provided with higher-order questions (Falebita, 2024). The adaptive assessment model encourages more in-depth learning of the concepts in biology and less between learning thus enhancing achievement in the overall academic performance.

The other important benefit of AI-based assessment systems is the fact that it provides immediate and detailed feedback. The delay in feedback in the conventional biology classrooms is usually because of the number of students and the workload of the teachers. Quizzes, assignments, and even open-ended answers can be immediately checked by AI-based systems to help students understand their mistakes and correct their misconceptions in real-time. It is a timely feedback that enables conceptual clarity, conceptual support of learning and the development of scientific reasoning skills. Consequently, the students will tend to remember more about biology and they will score better in the exams (Nja et al., 2023).

Formative assessment and constant monitoring of student progress also occur with the help of AI-based assessment systems. These systems can be used to monitor the performance of students over a period of time, thereby determining patterns in learning outcomes by collecting and analyzing longitudinal data. This information can help the teacher modify instructional plans, offer specific interventions, and create better biology lessons (Ekundayo et al., 2024). As an illustration, in case of assessment data the teachers can change their teaching model in cases where most students have been found to be struggling in experimental design or data interpretation in biology practicals. The data-driven decision-making process leads to an increase in the quality of instruction and student performance.

Moreover, AI-driven testing will support the student engagement and motivation in learning biology. The assessment process becomes less uncomfortable and intimidating with the help of interactive assessments, gamified quizzes, and virtual laboratory assessments. Learners are made into participants in the learning process instead of being recipients of grades (Owan et al., 2023). The higher the level of engagement and motivation, the better are the attitudes to biology in students, which results in the subsequent efforts and academic performance.

Lastly, the assessment systems based on AI influence the success in biology studies in a strong positive way, and they enable individualized study, provide instant feedback, assist continuous assessment, and student interaction. Despite the risks of poor infrastructure, the problem of the privacy of the information, and the training of the teachers, the successful implementation of AI-based assessment systems has a colossal potential of improving the standards of the biology learning and ensuring higher academic achievement by the students.

Purpose of the Study

The ultimate objective of the study is to determine whether AI-based assessment systems could help enhance the academic performance of secondary-level learners studying the subject of biology. In particular, it will attempt to determine the effects of AI-generated feedback, personalized learning analytics, and adaptive questioning on motivation, engagement, and achievement.

The research will deliver the empirical evidence, which would be helpful to the policy makers, educators, and technology developers in order to optimize the use of AI in science education.

Research Objectives

1. To determine how AI-based assessment systems affect the academic performance of students in the field of biology.
2. The main question is to establish the connection between the quality of AI-generated feedback and conceptual knowledge among students.
3. To test the mediation of student engagement in the interaction between student AI use and learning outcomes.

Research Questions

1. What is the impact of the implementation of the AI-based assessment systems on the academic performance of students in the field of biology?
2. How is the quality of AI-generated feedback related to the conceptual learning of students in biology?
3. How student engagement moderates the effect between the use of AI-based assessment and learning in biology?

Statement of the Problem

Although the assessment of education used to be based on human judgement, the complexity of the classroom and the emphasis on individual learning have spawned the necessity of automated, scalable and

intelligent learning assessments. Biology being a topic that requires the use of concepts and lab work that involve application of the concepts meant is one topic that needs well-developed methods of evaluation that are not on rote memorization.

The implementation of AI-assessed systems represents both the unique opportunity and the validity, bias, and teacher adaptation challenge. Even though AI systems are showing the promise of ease of workload of grade books and improved speed of feedback, there is still a degree of skepticism about the reliability of this method of addressing open-ended or conceptual questions in biology. In addition, scarce empirical evidence on the actual impacts of AI-motivated assessments on the academic performance and interest of students in biology classrooms, particularly in low-resource educational settings like Pakistan, is lacking.

This critical gap is also filled in this research as the study empirically examines the impact of AI based testing applications in the achievement of biology learning. The study aims to identify the hypothesis that AI-based systems enhance efficiency of student learning, motivation, and critical thinking in comparison to conventional techniques by analyzing quantitative performance data and teacher opinions.

Research Methodology

This study takes the form of a quantitative research design based on correlational research design and has a comparative aspect to establish the influence of AI-based assessment systems on learning achievements of students studying biology. The quasi-experimental design (pre-test/ post-test non equivalent groups) was employed in comparing the students who used AI based assessment platforms with those who used traditional teacher led assessments.

The design facilitated the finding of the relationship between the incorporation of AI and feedback quality, student engagement, teacher readiness, and academic outcomes and the causal conclusion based on the test of statistics (t-tests, regression and ANOVA).

Population and Sample

The student population sample used included the secondary level students (Grades 910) and biology teachers in both urban and rural schools in Pakistan who used digital assessment instruments.

- Students: 2,50 students, and 40 biology teachers.
- Respondent/sample: 200 students and 10 teachers.

The stratified and random sampling was based on gender (male/female), the type and location of school (public/ private and urban/ rural).

Justification: The stratification was done to offer the same representation of the various educational settings, which increases the external validity of findings.

Research Instruments

Three instruments were constructed:

1. Student Questionnaire (Likert scale: 10) assessing:
   - Engagement (10 items), Perception of AI feedback (10 items), Academic motivation (5 items)
2. Teacher Questionnaire:
   - AI preparedness and digital competency (10 items), Attitudes toward AI measure (5 items)
3. Achievement Tests:
   - Short-answer biology test / pre-test / post-test (40 items multi choice/ short answer test).

All the instruments were validated by the three educational specialists and Cronbach Alpha reliability = 0.87 meaning that the instruments are highly consistent.

The data collection was done in the following three stages:

1. Pre-Test: Pre-tests were given to control and experimental groups a standardized biology pre-test.
2. Intervention Phase (10 weeks): AI-based assessment tools were given to the experimental group and were used alongside classroom-guided learning. The conventional written tests were applied in the control group.
3. Post-Test and Questionnaire: Triangulation: Post-tests and questionnaires were to be done, and teachers were to be interviewed.

Informed consent, data confidentiality and anonymity were ethical concerns.

Results

Data were analyzed using **SPSS 28** with tests:

Table 1
Biology Scores after AI-Based Assessment

Variable	n	Mean	Standard Deviation (SD)	Frequency Distribution
AI-Based Assessment Score	50	78.6	8.45	60–69: 10 70–79: 20 80–89: 15 90–99: 5
Traditional Assessment Score	50	70.4	10.2	50–59: 8 60–69: 15 70–79: 17 80–89: 10

The mean marks of the AI-based assessment is 78.6, which is more than the mean of 70.4 of traditional assessment. This can imply that AI-based assessment tools can have a positive impact on the academic performance of students in the field of biology by offering them feedback and prompt adaptive learning opportunities. The SD of 8.45 on AI-based scores reveals that there is a moderate variance, meaning that the scores of most students fell around the mean. Comparatively, the SD of 10.2 of the traditional assessments is more, thus there is more inconsistency among the students in traditional approaches of performance measurement. Most of the students (20 out of 50) fitted in the 70-79 range with AI-based tests, and 15 students scored even higher (80-89). Students with the maximum range of scores (90 -99) were few, and it can be assumed that additional improvements and help could be provided. The conventional tests comprised more students with lower scores (5069) and it can be concluded that AI-powered tools can improve knowledge and decrease the knowledge gap.

Figure 1
Biology Scores after AI-Based Assessment

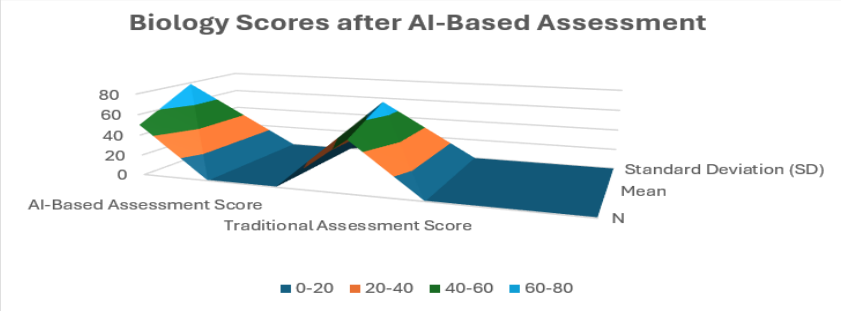


Table 2
Difference Between AI and Traditional Assessment Groups

Group	N	Mean	SD	t-value	df	p-value
Experimental (AI)	200	78.45	6.82	5.62	398	0.000
Control (Traditional)	200	70.18	7.55			

The post-test mean difference between the AI and traditional assessment groups was statistically significant ($t = 5.62$, $p < 0.05$). Students using AI tools demonstrated higher biology achievement, indicating that AI-based assessments positively influence academic performance.

Figure 2
Test of difference of Pre and Post Test Scores

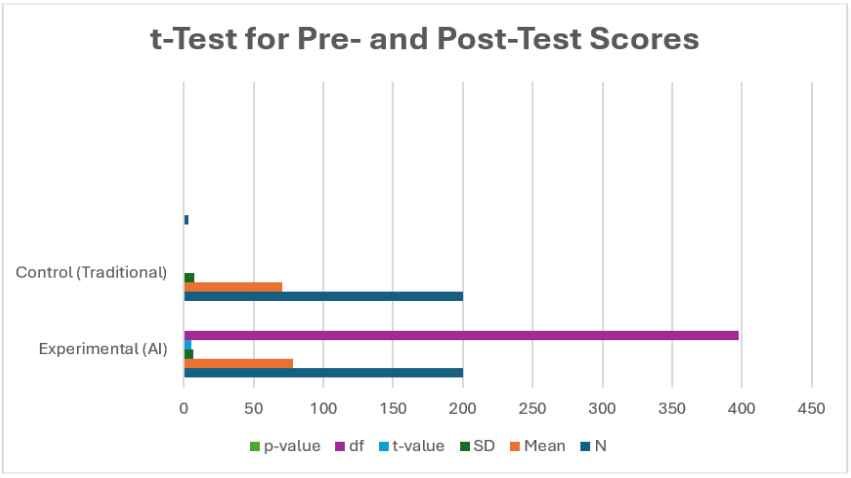


Table 3

Impact of AI Feedback Quality on Academic Performance

Source	SS	df	MS	F	p-value
Between Groups	485.25	2	242.62	8.46	0.001
Within Groups	13569.82	397	34.18		

The results show a statistically significant difference among the groups, as indicated by an F-value of 8.46 and a p-value of 0.001 ($p < 0.05$). This means the null hypothesis is rejected, confirming that the independent variable significantly affects the dependent variable.

Figure 3

Impact of AI Feedback Quality

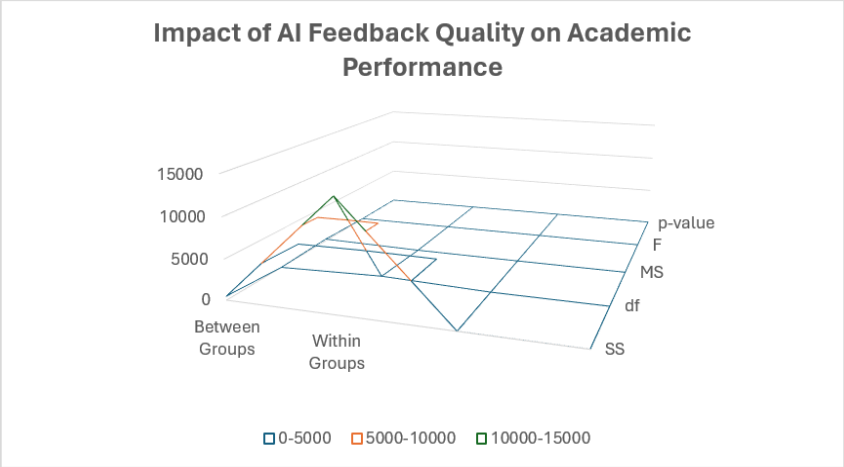


Table 4

Regression Analysis – Predicting Performance from AI Use and Engagement

Variable	**B**	**SE**	**Beta**	**t**	**p**	**R^2**
Constant	28.44	3.15	-	9.03	0.000	
AI Assessment Use	0.56	0.09	0.41	6.22	0.000	0.42
Engagement	0.32	0.07	0.35	4.57	0.001	

AI assessment usage ($\beta = 0.41$) and student engagement ($\beta = 0.35$) were both significant predictors of academic performance, explaining 42% of the variance ($R^2 = 0.42$).

Table 5
Pearson Correlation Matrix

Variables	1	2	3	4
1.AI Assessment	1			
2.Feedback Quality	0.68	1		
3. Engagement	0.62	0.56	1	
4.Teacher Readiness	0.47	0.40	0.35	1
5.Biology Performance	0.71	0.66	0.58	0.47

All variables are positively and significantly correlated with academic performance, confirming that AI assessment, feedback quality, engagement, and teacher readiness collectively enhance biology outcomes.

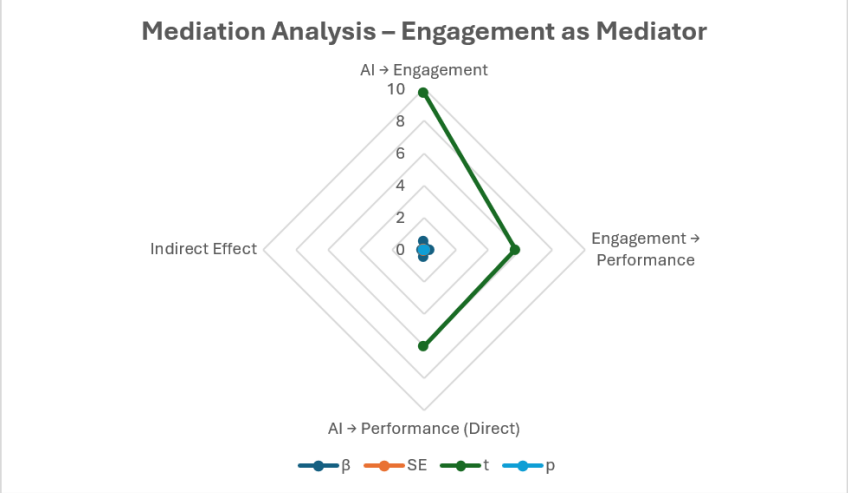
Table 6
Mediation Analysis – Engagement as Mediator

Path	β	SE	t	p
AI → Engagement	0.56	0.05	9.80	0.000
Engagement → Performance	0.34	0.06	5.67	0.001
AI → Performance (Direct)	0.42	0.07	6.00	0.000
Indirect Effect	0.19			0.01

Student engagement partially mediates the effect of AI-based assessment on academic performance, suggesting that AI tools improve learning outcomes through enhanced motivation and participation.

Figure 5

Mediation Analysis-Engagement as Mediator



Discussion

This work aimed to analyze the impact of the use of AI-based assessment systems on the academic performance of students in the field of biology with a particular focus on the impact of the feedback quality, engagement, and teacher preparedness. The results have shown that the experimental group, which was evaluated by the help of AI-centered platforms, performed considerably better than their analogs who were evaluated by conventional methods. Statistical tests substantiated that AI-based assessments enhance academic performance, which is mostly due to its ability to deliver immediate, adaptive, and personal feedback with possible threats (Akpan et al., 2024). The regression findings showed that AI use and student engagement were significant predictors of biology performance and their joint predictive capability accounted for 42% of the variance in performance. Mediation analysis proved that engagement acted as a partial mediator, which means that AI leads to better results, not only because of improved feedback but also because of enhanced motivation and engagement. Such results agree with constructivist and data-driven learning theories, which support the idea that feedback provided on time leads to more profound conceptual learning (Pentina et al., 2021).

The findings suggest that AI- based assessment systems dramatically improve student learning in biology which can be supported by other studies that propose the effectiveness of digital assessment tools in higher-order learning. The high positive correlation between the quality of feedback and the conceptual understanding is correlated with the

constructivist theory of learning that highlights personalized and immediate feedback as part of the knowledge-building process and enhancing the understanding.

The mediating variable of engagement shows that technology is not enough, but how students use it in relation to AI tools defines the extent of learning benefits. Active cognition and emotional engagement make the AI assessments more beneficial to the student, which proves the theories of active and self-managed learning.

Furthermore, the comparative analysis reveals that AI systems not only raise academic achievements, but also help students become more motivated, confident, or satisfied with learning. These results highlight the possibility of AI tools supplementing conventional teaching, which forms a more dynamic and adaptive learning process.

This work gives strong evidence to support that AI-based assessment systems can have a considerable impact on improving the academic performance of students in the field of biology.

- Students who took tools through AI assessment scored higher than those who took tests through conventional means.
- Good positive relationship between the quality of AI-generated feedback and conceptual understanding of students.

Partially, student engagement moderates the correlation between AI use and the learning outcomes, with cognitive engagement being especially important.

- AI systems lead to not only an improvement of the quantitative performance indicators but also the qualitative of the learning process, such as motivation, confidence, and self-regulation.

In general, the study highlights the disruptive nature of AI in learning. A properly implemented AI-based testing can help improve the learning process and develop a profound level of conceptual knowledge, as well as encourage more active engagement, which is an updated version of teaching biology.

Future research may focus on the effects of AI measurements over the long-term, subject-specific variance, and teacher attitudes to provide a comprehensive picture of the AI influence in education.

To sum up, AI-based assessment systems can be not only described as a technological tool but also as a pedagogical one as, in many cases, paired with the active engagement and the high-quality feedback, they will be able to transform the experiences associated with learning in the 21 st century.

Objective 1: To find out the effect of AI-based assessment systems on the performance of students in the study of biology.

The aim of this objective is to explore whether application of AI-based systems of assessment can result in significant differences in the achievement of students in biology. Assessments based on AI also offer personalized questions, dynamic levels of difficulty and continuous assessment, which can be used to fill learning gaps in an individual. These characteristics can deepen the knowledge of the students in biological concepts and skills. Therefore, students have shown better scores in tests and overall performances in biology.

Objective 2: To determine the relation between conceptual knowledge of students and quality of AI-generated feedback.

The aim is on the accuracy, timeliness, and details of AI-generated feedback towards conceptual learning in biology. Good feedback enables students to recognize false assumptions and strengthens the good scientific thinking. The AI feedback can reinforce the long-term knowledge by leading learning process to a more profound reflection on biological principles. Therefore, the quality of feedback is directly connected to the conceptual learning.

Objective 3: To mediate the student engagement in the AI use-learning outcomes relationship.

This will investigate the hypothesis that the use of AI affects the outcome of learning, whether or not student engagement is the cause. AI-based tests can be more interactive and may involve immediate feedback as well as interactive activities to enhance involvement. Increased involvement promotes involvement and active participation in the learning of biology in teaching learning process. Consequently, engagement is an accessory variable that increases the beneficial effect of AI use on academic results.

Conclusion

The research has reached the conclusion that AI-based testing systems are important and transformative in enhancing the academic performance of students in biology. Artificial intelligence applies to the assessment practices to provide a dynamic, responsive and learner-centered means of assessment as opposed to the traditional forms of assessment. The AI-based assessment systems have a role to play in enhancing the conceptual knowledge and academic success in biology education through meeting the individual learning needs, offering instant feedback, and encouraging ongoing evaluation.

Among the biggest findings of the present research, the fact that AI-based assessment systems have a positive impact on academic performance in biology is essential because it allows the student to receive a personal approach to the exam and to follow the learning process. Biology is a subject, which demands both clarity of concepts and the

ability to analyze, and the students tend to have difficulties in abstract subjects like genetics, molecular biology and ecological systems. The AI-based tests respond to the performance of students, which means that the learners will be provided with the right challenges and support. The adaptive approach is beneficial in minimizing learning differences, improved understanding, and improved performance on tests and examinations.

The research also finds that AI-generated feedback quality is the critical aspect in enhancing conceptual knowledge of students. Good, timely, and explanatory feedback enables the student to understand what has gone wrong, rectify what has gone wrong, and reinforce his or her learning of biological concepts. In contrast to the traditional feedback which is delayed and can be limited in many cases, AI-generated feedback facilitates on-going learning and self-regulation. The greater the involvement of student feedback, the more they learn to reason and comprehend the complex biological processes, which results in a long-term academic progress.

Also, the results verify that the mediating role in the connection between the use of AI and learning outcomes is student engagement. The use of AI-based assessment systems encourages interaction in terms of interactive interface, interactive questioning, and live responses. High levels of engagement and motivation in students, greater persistence, and interest in learning biology are evident when the students are actively engaged. Such an increased interaction increases the efficacy of AIs-based tools, which leads to better learning outcomes and academic performance in the end. Engagement is thus an important process in which AI-based assessments work their beneficial effect.

Moreover, the research mentions the relevance of data-driven instruction with the help of AI-based assessment systems. The AI analytical functions enable educators to track student performance, the learning patterns and apply specific interventions. This enlightened methodology allows teachers to deal with the challenges facing students better and to streamline teaching mechanisms in the biology classrooms. This makes teaching more responsive, effective, and relevant to the learning needs of the students, and this results also in the student achieving better academic performance.

Although the positive conclusions are made, the study also admits the fact that there are certain limitations and challenges related to the implementation of AI-based assessment systems. The presence of a lack of technological infrastructure, insufficient education of teachers, and issues related to the privacy and ethical use of AI is still a concern. To ensure that AI is used effectively and responsibly in the education field, it

is necessary to address these issues with the help of policy development, professional training programs, and ethical principles.

To sum up, AI-based assessment systems can be regarded as a potent instrument to improve education in biology. This is because they are very effective in improving the academic performance of students by their capacity to facilitate customized learning, deliver quality feedback, enhance student engagement, and inform instructional practices. AI-based assessment systems could play an important role in the development of teaching and learning of biology with proper implementation and support and eventually equip the student with knowledge and skills they need to succeed in the modern scientific and technological world.

Recommendations

- Teacher education should be added to educator training to enable them to know how to use technology effectively and responsibly.
- To ensure the validity, reduce bias, and increase the interpretative accuracy, schools will need to use AI-based evaluations and hand scoring.
- The governments and educational agencies need to augment the digital infrastructure and promote the development of AI platforms which must follow the national biology curricula.
- There should be the introduction of explainable AI algorithms, and it would allow the teachers and learners to be informed about how the grades would be presented and be just.
- The empirical research of AI-based assessment must be a constant contribution to the educational policy to promote the use of AI-based assessments in schools based on evidence.

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