EFFECTS OF E-LEARNING ON THE ACADEMIC ACHIEVEMENT OF BIOLOGY STUDENTS IN SELECTED SENIOR SECONDARY SCHOOLS IN KUJE AREA COUNCIL, FCT-ABUJA NIGERIA

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Abstract
This study explores how e-learning platforms can meaningfully improve biology learning outcomes among Senior Secondary School II students in Kuje Area Council, Abuja, during the 2023/2024 academic session. Through a quasi-experimental design, researchers worked with two schools, designating one as the experimental group where students engaged with e-learning tools and the other as the control group, which continued with traditional classroom instruction. The population of the study consisted of 1,525 SS II students (869 males and 656 females) out of which 105 (56 males and females 49) Biology students II from the two randomly selected senior secondary schools in Kuje Educational Zone, Abuja formed the sample size for the study. The instrument used for data collection was Biology Achievement Test (BAT). The reliability of the instruments was established using Pearson moment correlation coefficient for BAT which yielded a reliability index of 0.78. Data was analysed using mean and standard deviation for research questions while t-test was used to test the hypotheses at 0.05 level of significance. The findings revealed compelling evidence of e-learning's effectiveness. Students in the experimental group demonstrated substantial academic gains, with their post-test mean scores significantly surpassing their pre-test performance Additionally, the analysis showed no significant differences in achievement between male and female students, suggesting that e-learning benefits students equitably regardless of gender. These results highlight the transformative potential of e-learning platforms in biology education and recommends that their strategic integration into secondary education could contribute meaningfully to enhancing educational quality and supporting broader national development goals.

Keywords: E-learning, Academic Achievement, Senior Secondary Schools, Biology, Kuje-Abuja, Nigeria

Introduction
The rapid advancements in science and technology have significantly increased the need for continuous knowledge updates (Babagana & Abubakar, 2025). In recent years, technology integration has fundamentally transformed the landscape of traditional teaching and learning methods (Alam, 2022). One prominent aspect of this transformation is the widespread adoption of e-learning platforms, which utilize electronic technologies to deliver educational content and facilitate interactive learning experiences. Across the educational landscape, e-learning has steadily gained prominence, transforming instructional delivery from primary classrooms to

university lecture halls, offering new opportunities to improve the quality and accessibility of education (Matthew et al., 2021). However, its specific impact on science subjects such as Biology and students' academic achievement remains a subject of ongoing research and debate.

Modern classrooms have witnessed a paradigm shift as digital ICT integration has brought fresh dimensions to teaching methodologies and learning experiences, preparing students for the demands of the 21st century. Teachers now need to acquire basic ICT knowledge and skills as set of the requirements to deliver educational services through ICT platforms. Recent developments indicate many ICT applications becoming a general knowledge that has become an open source to all and sundry, which in turn, has brought about the improvement of the standard of various ICT developers across the globe (Information Communication and Technology and Sustainable Development Goals, 2017). Keeping in mind the advantages of integrating ICT into instruction, Science teachers must continually update their knowledge of available ICT tools to enhance instructional effectiveness.

Science, in particular, is regarded as the foundation of modern technological breakthroughs, underpinning nearly every technological innovation seen in the world today (Babagana, etal. 2021). Science is also viewed as the foundation of modern development and the connection among innovation technology and socio-economic development (Abubakar et al., 2021). Science education pursues interconnected goals: first, to develop learners' knowledge, skills, and attitudes that foster personal autonomy and community contribution (Apochi & Abubakar, 2017); and second, to nurture scientifically literate citizens equipped for rational analysis and informed action (Ebele & Abubakar, 2018). These objectives carry profound implications, as science education possesses the transformative capacity to fundamentally reshape both individual perspectives and societal structures (Abubakar, 2024). However, teaching and learning in the recent days is rooted in the increasing prevalence of e-learning in educational settings worldwide and the growing significant of science in secondary schools (de-Souz-Rodrigues *et al*., 2021). As digital technologies continue to evolve rapidly, e-learning has become a viable alternative to traditional classroom instruction, providing students with access to an extensive array of educational resources and tools. Its integration into education motivates researchers to explore LMS as a tool for facilitating e-learning (Muhammed & Abubakar, 2024). According to a recent report by Research and Markets, the global e-learning market is expected to reach $374.3 billion by 2026, driven by factors such as increasing internet penetration, increasing emphasis on individualized learning experiences, and the growing adoption of mobile learning solutions (Research and Markets, 2021).

In the context of secondary education, Biology is described as the study of life, delving into how living organisms operate, evolve, and interact within their environment (Nwankwo, 2024). Akande, Mogbo, Bello and Yaki (2018) posited that the subject is taught to senior secondary school students in Nigeria and stands as one of the country's three core science subjects. However, teaching biology effectively can be challenging, as it often involves abstract concepts and complex phenomena that may pose challenges for students to grasp through conventional methods alone. E-learning platforms present an opportunity to address these challenges by providing interactive simulations, multimedia resources, and adaptive learning tools that

cater to students' diverse learning styles and preferences (Turan & Gulbahar, 2020).

Educational technology, as defined by Otto and Becker, (2019) in their study as the use of electronic technologies to access educational curriculum outside of a traditional classroom, has significantly transformed the educational landscape, especially in the field of biology education. Virtual learning refers to educational materials, tools, and platforms that are accessible online which facilitate the learning process in a virtual or digital environment (Abubakar, et al., 2025). E-learning refers to the use of electronic technologies, particularly the internet, to deliver educational content and facilitate interactive learning experiences (Chebichi et al., 2024). Historically, e-learning began as simple computer-based training programs in the 1960s and evolved with the advent of the internet in the 1990s, which enabled the delivery of educational content online. In this study, e-learning includes a wide range of tools and resources such as virtual laboratories, interactive simulations, and online assessments that enhance the learning experience for biology students.

The recent surge in e-learning adoption, particularly accelerated by the COVID-19 pandemic, has highlighted its potential to provide flexible, personalized, and engaging learning experiences. Studies revealed that e-learning can significantly improve student engagement and academic performance by providing interactive and accessible learning environments (Dhawan, 2020; Bond et al., 2021). For instance, e-learning offers a range of benefits, including flexibility, interactivity, and accessibility, which can enhance student engagement and learning outcomes in Biology education (Albright & Park, 2015). Research conducted by Means et al., (2013) found that e-learning methods, when appropriately implemented, can improve student performance and satisfaction in science subjects, including Biology. Dhawan (2020) emphasized that e-learning's flexibility allows students to learn at their own pace and convenience, which is particularly beneficial in complex subjects including biology. As a platform for real-time education, virtual or e-learning has been embraced by students for its interactive nature and accessibility (Abubakar, et al., 2025). A recent investigation by Abubakar (2024) demonstrates that e-learning serves as a powerful mechanism for enhancing biology student performance by facilitating collaborative learning experiences and peer interaction, enabling learners to grasp and implement concepts more effectively. The virtual environment also empowers students to customize their learning experience, progressing at individualized speeds while concentrating on areas of personal interest. Supporting this perspective, Nwankwo and Okigbo (2024) found that Electronic Learning Methods (ELM) surpass Conventional Learning Methods (CLM) in boosting students' biology performance. Bond et al. (2021) further emphasized that interactive digital learning platforms promote superior conceptual comprehension and knowledge retention when compared with traditional pedagogical approaches. Collectively, these research outcomes highlight e-learning's significance and efficacy in modern educational setting, establishing it as a central element in this study's investigation of academic performance in biology education.

Moreover, a meta-analysis by Wang et al., (2022) supports these findings, revealing a significant positive effect of e-learning interventions on students' academic achievement across various educational settings. This comprehensive analysis reviewed multiple studies and concluded that students using e-learning tools

generally performed better on assessments and demonstrated a deeper conceptual understanding of biology. The meta-analysis emphasized that the success of e-learning is not confined to a specific educational setting but is broadly applicable, benefiting students in diverse environments. These findings underscore the potential of e-learning to transform biology education, providing both teachers and students with effective tools to enhance teaching and learning outcomes.

However, despite the potential benefits of e-learning in biology education, several challenges and barriers exist that may hinder its effective implementation. One significant challenge is the technology infrastructure required to support e-learning. Many educational institutions, particularly in developing regions, may lack the necessary hardware, software, and technical support to fully implement e-learning programs (Ally, 2020). This includes the availability of computers or tablets for students, as well as the platforms and software needed to deliver interactive and engaging biology content. Inadequate infrastructure can result in a subpar e-learning experience, where students and teachers struggle with technical issues rather than focusing on educational content. To support this, Mwakyusa et al., (2015) assert that some countries have made significant investments in e-learning initiatives, others face challenges related to connectivity and resource constraints. Akande et al., (2018) lamented that while e-learning may be an attractive teaching method for both teachers and students, several challenges, such as electrical instability, inadequate funding, the high cost of biology software and bandwidth, insufficient ICT skills, and student attitudes, can detract from the effectiveness of the teaching process in secondary schools. This might pose a challenge to students' academic achievement. However, there is growing recognition of the potential of e-learning to overcome barriers to education and improve learning outcomes in Biology. Initiatives such as the African Virtual University (AVU) have been instrumental in promoting e-learning in Biology education across the continent (Materu, 2016). The AVU offers online courses, virtual laboratories, and interactive multimedia resources tailored to the needs of African students, providing access to quality education regardless of geographical location.

The background to this study underscores the importance of exploring the intersection between e-learning, biology, and students' academic achievement in the context of secondary schools. By addressing this gap in the literature, this research aims to contribute to the ongoing discourse on educational technology integration and pedagogical innovation, with implications for curriculum development, teacher professional development, and educational policy formulation.

Statement of the Problem

The rapid evolution of digital technologies has revolutionized the landscape of education, with e-learning emerging as a prominent approach to delivering instructional content and facilitating interactive learning experiences. In recent years, there has been a growing emphasis on the integration of e-learning platforms in secondary education, aiming to enhance the quality and accessibility of learning resources for students. However, despite the widespread adoption of e-learning, questions remain regarding its effectiveness in improving students' academic achievement, particularly in subject areas such as biology. Past research has provided insights into the potential benefits of educational technologies in enhancing students' engagement, motivation, and conceptual understanding of integrated

science concepts (Lee et al., 2023). However, there is a need for further investigation into the specific impact of educational technologies, for example e-learning on students' academic achievement in sciences particularly biology, as well as the factors influencing its successful implementation in secondary schools.

Moreover, the challenges and barriers associated with e-learning in secondary education, including issues related to technology infrastructure, teacher training, and digital literacy, require careful consideration (Ally, 2024). Additionally, the proliferation of online educational resources raises concerns about the quality and credibility of content available to students. Addressing these challenges and understanding the dynamics educational technologies such as e-learning in science especially biology education is essential for informing evidence-based instructional practices and improving educational outcomes in secondary schools. Therefore, this study aims to investigate the effect of e-learning on biology students' academic achievement in selected secondary schools in Kuje Area Council Abuja, providing valuable insights into the potential benefits and challenges of integrating educational technologies such as e-learning into secondary-level biology instruction.

Purpose of the Study

The aim of the study is to investigate the effect of e-learning on the academic achievement of biology students in selected Senior Secondary Schools in Kuje Area Council, Abuja. The specific objectives of the study are to:

1. determine the effect of e-learning on the academic achievement of biology students in selected secondary schools in Kuje Area Council.
2. find out the effect of e-learning on the students' academic achievement in biology based on gender in Kuje Area Council

Research Questions

The following research questions guided the study:

1. What is the difference in the mean achievement scores of biology students taught using e-learning and their counterpart taught using conventional teaching method?
2. What is the difference in the mean achievement scores of male and female biology students when exposed to e-learning in Kuje Area Council?

Hypotheses

Ho_1: There is no significant difference in the mean achievement scores of students in biology between those exposed to e-learning and their counterpart taught with conventional teaching method.

Ho_2: There is no significant difference in the mean achievement scores of male and female students taught biology using e-learning platforms.

Methodology

This study employs a quasi-experimental design to investigate the effectiveness of e-learning platforms in enhancing Biology education within selected senior secondary schools in Kuje Area Council, Abuja. Quasi-experimental research design is frequently used when it is not logistically feasible or ethical to conduct a randomized controlled trial (Shrutika, 2023). This research design was used based on the utilization of intact classes for the study. The population of this study consisted of 1,525 SS II biology students (869 males and 656 females) out of which 105 Biology

students II from the two randomly selected senior secondary schools in Kuje Educational Zone, Abuja formed the sample size for the study in the 2023/2024 academic session. The reason for the choice of this class was that SSII students were not new to biology and as such would have acquired the basic pre-requisite knowledge in the subject. Also, at this level they are not likely to face any imminent external examination. In addition, they are not affected by new environment into the new level of education like the SS1 class. Based on this consideration, the SS2 Biology students were considered more appropriate for the study.

A multistage sampling procedure was used to draw the sample. At the first stage, purposive sampling technique was used to select two senior secondary schools, one public and one private school. In the second stage, simple random sampling technique was used to select one intact class of SSII Biology students from each sampled schools in Kuje Educational Zone, making a total of 105 students (56 males and females 49) which formed the sample size. Finally, one school (Private) was randomly assigned experimental group while the other school (Public) as control group using balloting. The experimental group was taught through the e-learning platform, while the control group was taught using conventional teaching method. The e-learning platform served as a key instrument in this study, providing online instructional tools and resources to assess its effects on biology students' academic achievement in selected senior secondary schools. The Biology Achievement Test (BAT) consisted of two sections: Section A and section B. Section A was for demographic information of the respondents while section B was for academic achievement assessment. Section B consisted of 30 multiple-choice questions designed to evaluate students' academic achievement of biology concepts covered during the study period. The research instruments underwent construct and content validity (table of specification) by two biology education lecturers and two secondary school biology teachers. Their corrections and feedback were incorporated to ensure clarity, relevance, and alignment with the research objectives.

To establish the reliability of the research instruments, a pilot test was conducted with a sample of students and teachers from non-participating schools. The reliability coefficient was determined using person product moment correlation coefficient yielding a value of 0.78. This result indicates a high level of internal consistency, demonstrating that the instruments are reliable and dependable for measuring the effect of e-learning on biology students' academic achievement. Data collection commenced following the acquisition of authorization from school administrators and informed consent from participants. Pre-tests were administered to both the control and experimental groups to assess their initial academic performance in biology. Following this, e-learning interventions were implemented in the experimental group, while the control group continued with conventional teaching method. After the intervention period, post-tests were conducted to measure changes in academic performance and evaluate the impact of e-learning on the students' achievement in biology. Descriptive statistics, specifically mean and standard deviation, were employed to address all research questions, while inferential statistics utilizing the t-test were applied to test the hypotheses using Statistical Package for Social Sciences (SPSS) version 27 at a 0.05 significance level.

Results and Discussion

This section presents the findings of the study, analysing the data collected and discussing the results in relation to the research objectives and existing literature.

Answer to Research Questions

Research Question One

What is the difference in the mean achievement scores of students taught using e-learning and their counterpart taught using conventional teaching method?
To answer this research question, frequency count, mean and standard deviation were used and the result set out on table 1.

Table 1: The effect of e-learning on the academic achievement of biology students in selected secondary schools in Kuje Area Council, FCT-Abuja

Group	N	Pre-test Mean	SD	Post-test Mean	SD	Mean Difference
Experimental Group	46	18.13	3.17	37.17	4.98	6.04
Control Group	59	19.04	2.59	31.13	4.63	
Mean Difference		0.91		6.04		

Table 1 indicated that the pretest mean achievement scores of students taught using e-learning and those taught using conventional method were 18.13 and 19.04 respectively, with standard deviations of 3.17 and 2.59. This shows that both groups were relatively comparable in achievement before treatment, as the observed mean difference of 0.91 is minimal. However, the post-test mean achievement scores of students taught using e-learning (37.17) were higher than those of students taught without e-learning (31.13), with standard deviations of 4.98 and 4.63 respectively. The post-test mean difference of 6.04 indicates that students taught using e-learning performed better than their counterparts taught without e-learning.

Research Question Two

What is the difference in the mean achievement scores of male and female biology students when exposed to e-learning in Kuje Area Council?
To answer this research question, frequency count, mean and standard deviation were used and the result set out on table 2.

Table 2: The effect of e-learning on the academic achievement of male and female biology students in selected secondary schools in Kuje Area Council, FCT-Abuja

Group	n	Pre-test Mean	SD	Post-test Mean	SD	Mean Difference
Male	32	18.63	3.15	37.75	5.15	1.89
Female	14	17.00	3.01	35.86	4.47	
Mean Difference		1.63		1.89		

Results in Table 2 indicate that the pretest mean achievement scores of male and female students were 18.63 and 17.00 respectively, with standard deviations of 3.15 and 3.01. This shows that the difference in achievement between male and female students before treatment was minimal, indicating that both groups were relatively comparable at the pretest level. Furthermore, the post-test means achievement scores of male students (37.75) were slightly higher than those of female students (35.86), with standard deviations of 5.15 and 4.47 respectively. Although male students recorded a higher mean score, the observed mean difference of 1.89 suggests that the difference in achievement between male and female students was relatively small.

Hypotheses

Hypothesis One

Ho_1: There is no significant difference in the mean achievement scores of students in biology between those exposed to e-learning and their counterpart taught with conventional teaching method.

To test for the hypothesis, t-test statistic was used and results presented in table 3.

Table 3: summary t-test on the significant difference in the mean achievement score of biology students who used e-learning tools and those taught using conventional method of teaching in Kuje Area Council FCT-Abuja

Group	N	Mean	SD	t-value	df	p-value	Decision
Experimental Group	46	37.17	4.98				Rejected
Control Group	59	31.13	4.63	6.03	90	0.00	

Results in Table 3 showed the summary of the independent samples t-test analysis conducted to investigate potential significant differences in mean achievement score between those exposed to e-learning and their counterpart taught with conventional teaching method in Kuje Area Council, Abuja. Experimental Group recorded a mean achievement score of 37.17 (SD=4.98), while Control Group achieved a mean score of 31.13 (SD=4.63). The analysis produced a t-value of 6.03 and a P-value of 0.00, falling below the 0.05 significance threshold. This finding reveals statistically significant difference in academic performance between those exposed to e-learning and their counterpart taught with conventional teaching method leading to the rejection of the null hypothesis. Consequently, e-learning demonstrate a significant positive influence on biology students' achievement in Kuje Area Council.

Hypothesis Two

HO_2: There is no significant difference in the mean achievement scores of male and female students taught biology using e-learning platforms in selected secondary schools in Kuje Area Council, Abuja. To test for the hypothesis, t-test statistic was used and results presented in table 4.

Table 4: Summary of t-test on the significant difference in the mean academic achievement of male and female biology students who used e-learning tools in selected secondary schools in Kuje Area Council, FCT-Abuja

Group	N	Mean	SD	t-value	df	p-value	Decision
Male	32	37.75	5.15				Accepted
Female	14	35.86	4.47	1.51	90	0.13	

Results in Table 4 showed the summary of the independent samples t-test analysis conducted to investigate potential significant differences in mean achievement score between male and female biology students using e-learning tools in selected secondary schools within Kuje Area Council, Abuja. Male students recorded a mean achievement score of 37.75 (SD=5.15), while female students achieved a mean score of 35.86 (SD=4.47). The analysis produced a t-value of 1.51 and a P-value of 0.13, exceeding the 0.05 significance threshold. This finding reveals no statistically significant difference in academic performance between male and female students utilizing e-learning tools. Consequently, the null hypothesis is retained, indicating that e-learning tools exert comparable effects on achievement for both male and female biology students.

Discussion of Findings

The results from Table 1 revealed that the pretest and post-test mean achievement scores of students taught using e-learning and those taught using conventional teaching method. The experimental group and control group pre-test and post-test were 18.13 and 19.04 (SD= 3.17 and 2.59). However, the post-test mean achievement scores of students taught using e-learning (37.17) were higher than those of students taught using conventional teaching method (31.13), with standard deviations of 4.98 and 4.63 respectively. The post-test mean difference of 6.04 indicates that students taught using e-learning performed better than their counterparts taught using conventional teaching method. These findings align with other studies, such as Aytekin et al. (2016), who also found a notable improvement in academic performance among students using e-learning tools in various subjects. Similar results were observed by Shahzad et al. (2020), where students using digital learning platforms showed higher retention and achievement rates compared to those using traditional methods. The findings lend a support to that of Abubakar (2024) whose study showed that there was significant difference in the achievement mean scores of students taught Biology with Virtual Learning Strategy and those taught with conventional teaching method, indicating that Virtual Learning instruction is a good instructional method relative to conventional method, and that it can be used to improve students' achievement in Biology. However, this study contrasts with Kintu et al. (2017), who found no significant difference in performance between e-learning and face-to-face instruction, suggesting that factors such as infrastructure, student readiness, and content design play a role in the effectiveness of e-learning.

Table 2 showed a marginal difference between the academic achievements of male and female students exposed to e-learning. The post-test mean achievement scores of male students (37.75) were slightly higher than those of female students (35.86), with standard deviations of 5.15 and 4.47 respectively, the observed mean difference of 1.89 suggests that the difference in achievement between male and female students was relatively small.

The small difference suggests that e-learning tools can benefit both genders almost equally. This outcome resonates with research by Bernard et al. (2014), which found that gender differences in e-learning are generally minimal when the technology is effectively integrated. Similarly, studies by Al-Hebaish (2012) confirm that both male and female students exhibit comparable engagement and performance when using e-learning tools. However, while these results indicate parity, some studies, like those by Yukselturk and Bulut (2019), note that females tend to perform slightly better in online learning environments due to higher self-regulation skills, which may explain the slight advantage seen in this study.

The results in Table 3 showed the t-test analysis conducted to investigate potential significant differences in mean achievement score between those exposed to e-learning and their counterpart taught with conventional teaching method. Experimental Group recorded a mean achievement score of 37.17 (SD=4.98), while Control Group achieved a mean score of 31.13 (SD=4.63). The analysis produced a t-value of 6.03 and a P-value of 0.00, falling below the 0.05 significance threshold. This finding reveals statistically significant difference in academic performance between those exposed to e-learning and their counterpart taught with conventional teaching method leading to the rejection of the null hypothesis. Consequently, e-learning demonstrate a significant positive influence on biology students' achievement in Kuje Area Council. This finding strongly supports the hypothesis that e-learning positively impacts academic performance, consistent with earlier studies by Nguyen (2015), who found that e-learning significantly improves learning outcomes. Similarly, Alemu (2015) reported enhanced engagement and knowledge retention among students exposed to digital learning environments. In contrast, some studies, like those by Yang et al. (2014), indicate that without adequate learner support, the benefits of e-learning may not be fully realized, particularly for students who are less familiar with technology. Results in

Table 4 shows the summary of the independent samples t-test analysis conducted to investigate potential significant differences in mean achievement score between male and female biology students using e-learning tools in selected secondary schools within Kuje Area Council, Abuja. Male students recorded a mean achievement score of 37.75 (SD=5.15), while female students achieved a mean score of 35.86 (SD=4.47). The analysis produced a t-value of 1.51 and a P-value of 0.13, exceeding the 0.05 significance threshold. This finding reveals no statistically significant difference in academic performance between male and female students utilizing e-learning tools indicating that e-learning impacts both genders similarly. This aligns with research by Zander et al. (2016), who found no significant gender differences in the effectiveness of e-learning interventions. Studies like those by Hargittai and Shafer (2006) also indicate that once both male and female students have equal access to technology, performance differences tend to diminish. Similarly, Nwankwo and Okigbo (2024) study revealed that there was no significant difference between the mean achievement scores of male and female senior secondary school students taught Biology using E-learning method (ELM). Also, a study by Abubakar (2024) revealed that Virtual Learning Strategy enhances the performance of both male and female biology students. In a recent study by Katcha et. al (2025) revealed that there was no significant gender-based differences in either awareness or utilization of Virtual learning resources among pre-service science teachers. These findings underscore

the equalizing potential of e-learning, counteracting traditional gender biases in education, as noted by Owusu-Agyeman and Larbi-Siaw (2018).

Conclusion

The study has shown that the implementation of e-learning significantly enhances the academic achievement of biology students in Kuje Area Council Abuja. The results indicated that students' mean scores improved notably from pre-test to post-test after utilizing e-learning tools. This improvement in achievement was consistent across both male and female students, suggesting that e-learning is beneficial regardless of gender. These findings indicated that e-learning can be a powerful tool for enhancing students' academic performance in biology, particularly when implemented effectively in educational settings.

Recommendations

Drawing from the study's findings, the following recommendations are proposed to enhance biology education through e-learning implementation:

1. Schools should integrate e-learning tools into the biology students' curriculum to enhance student participation and comprehension of complex concepts. Professional development initiatives for educators on how to effectively implement e-learning strategies should be prioritized.
2. Resources must be distributed more fairly across government and privately-owned schools to guarantee universal student access to digital learning technologies. Government policies should focus on bridging the technological gap in public schools.
3. Despite the absence of notable performance disparities between genders, deliberate measures to boost female engagement in science, technology, engineering, and mathematics fields through specialized online educational strategies is imperative.
4. E-learning platforms should include mechanisms for continuous assessment and feedback to enable learners monitor their academic development and motivate them to improve their performance.

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