EFFECTIVENESS OF AI-BASED EVALUATION TOOLS IN ENHANCING TEACHING EFFECTIVENESS IN SCIENCE CLASSROOMS IN LAGOS STATE, NIGERIA

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Abstract

Teaching effectiveness in science classrooms has remained inconsistent due to limitations in traditional evaluation methods, thereby necessitating the integration of AI-based evaluation tools to enhance instructional quality. This study examined the effectiveness of AI-based evaluation tools in improving teaching effectiveness in science classrooms in Lagos State, Nigeria. The study adopted a quantitative explanatory design using the AI-Based Evaluation Tools and Teaching Effectiveness Questionnaire (AIETTEQ). The instrument was validated through expert review and pilot testing, while reliability was established using Cronbach's alpha coefficient of 0.87. A sample size of 300 science teachers was selected through multistage sampling techniques comprising stratified and simple random sampling. Findings revealed that AI-based evaluation tools significantly improved feedback quality ($\beta = 0.71$, $p < 0.05$), enhanced instructional adaptability ($\beta = 0.71$, $p < 0.05$), and increased overall teaching effectiveness ($\beta = 0.70$, $p < 0.05$), leading to the rejection of all null hypotheses. These results indicate that AI tools facilitate timely feedback, support adaptive teaching, and improve learning outcomes. The study concluded that AI-based evaluation tools are critical drivers of effective teaching in science classrooms. It is recommended that educational institutions integrate AI tools into instructional systems and provide continuous teacher training to maximise their potential.

Keywords: Artificial Intelligence, Teaching Effectiveness, Science Education, Instructional Adaptability, Feedback Quality

Introduction

The persistent concern within science education in Lagos State is not the absence of teaching effort but the uneven translation of that effort into measurable teaching effectiveness. Although classrooms are active, syllabi are covered, and assessments are routinely administered, evidence suggests that conventional assessment practices do not always provide a clear and comprehensive picture of students' learning, making it difficult to identify learning gaps and guide instructional improvement (Black & Wiliam, 1998; Shepard, 2000; Hattie & Timperley, 2007). This disconnect raises a fundamental problem: how can teaching effectiveness in science classrooms be systematically enhanced when traditional evaluation mechanisms remain largely subjective, delayed, and insufficiently diagnostic? At the heart of this problem lies the growing recognition that conventional evaluation practices, such as periodic tests, manual grading, and anecdotal feedback, function like rear-view mirrors: they reveal what has already occurred but provide limited guidance for immediate instructional adjustment and real-time support for learning (Black & Wiliam, 1998; Sadler, 1989; Hattie & Timperley, 2007; Wiliam, 2011).

At the heart of this problem lies the growing recognition that conventional evaluation practices, such as periodic tests, manual grading, and anecdotal feedback, function like rear-view mirrors; they show what has happened but offer limited guidance for immediate instructional adjustment. The need, therefore, is for evaluation systems that operate more like a dashboard, providing real-time, actionable insights capable of informing pedagogical decisions as they unfold.

These tools extend beyond mere automation; they embody adaptive intelligence, capable of identifying misconceptions, predicting learning trajectories, and recommending tailored instructional strategies (Holmes et al., 2022; Zawacki-Richter et al., 2021). In the context of science classrooms, where conceptual understanding often hinges on cumulative knowledge and abstract reasoning, such tools offer the potential to illuminate the often opaque processes of student cognition.

Teaching effectiveness, within this study, is conceptualised as the extent to which instructional practices facilitate meaningful student understanding, engagement, retention, and application of scientific concepts. It encompasses clarity of explanation, responsiveness to student needs, alignment of assessment with learning objectives, and the capacity to foster higher-order thinking. Teaching effectiveness is not a static attribute but a dynamic interplay of instructional design, delivery, and feedback mechanisms. It is akin to conducting an orchestra; the teacher must not only know the score but also continuously adjust tempo, tone, and balance in response to the performance of the ensemble. Without accurate and timely evaluation, even the most skilled conductor risks losing harmony.

Science classrooms present unique challenges that amplify the importance of effective evaluation. Scientific knowledge is hierarchical, with each concept building upon prior understanding. A single misconception, if undetected, can cascade into broader learning difficulties. Traditional evaluation methods often fail to capture the complexities and nuances of student learning, as they tend to emphasize summative judgments of achievement rather than providing continuous feedback that supports learning and improvement (Black & Wiliam, 1998; Sadler, 1989; Stiggins, 2005).

AI-based evaluation tools, by contrast, can dissect student responses at a granular level, identifying patterns that may elude human observation. For instance, machine learning algorithms can analyse students' problem-solving steps to pinpoint specific conceptual gaps, much like a medical diagnostic tool that detects underlying conditions rather than merely observing symptoms (Luckin et al., 2022).

The theoretical grounding of this study draws from several complementary frameworks that illuminate the mechanisms through which AI-based evaluation tools may influence teaching effectiveness. The Technological Pedagogical Content Knowledge (TPACK) framework underscores the integration of technology, pedagogy, and subject matter knowledge as essential for effective teaching in digital contexts (Mishra & Koehler, 2020). Within this framework, AI-based evaluation tools are not peripheral add-ons but integral components that reshape pedagogical strategies and content delivery. Their effectiveness depends on the teacher's ability to interpret and act upon the insights generated, thereby bridging the gap between data and instruction.

In parallel, the Feedback Intervention Theory (FIT) provides a lens for understanding how feedback influences performance. The theory posits that feedback is most effective when it is timely, specific, and aligned with task goals (Kluger & DeNisi, 1996) as extended in recent studies such as Wisniewski et al., 2020). AI-based evaluation tools operationalise these principles by delivering immediate and personalised feedback, thereby enhancing the feedback loop that is central to teaching effectiveness. In essence, these tools transform feedback from a periodic event into a continuous process, enabling teachers to recalibrate their instructional approaches in real time.

Constructivist learning theory further enriches the conceptual foundation of this study by emphasising the active role of learners in constructing knowledge. From this perspective, evaluation is not merely a mechanism for measuring learning but a critical component of the learning process itself. AI-based tools, with their capacity for adaptive assessment, align with constructivist principles by providing learners with opportunities to engage with content at varying levels of complexity and receive feedback that supports their individual learning pathways (Ifenthaler & Schumacher, 2021). The classroom, therefore, shifts from a one-size-fits-all environment to a more personalised learning ecosystem.

Despite these theoretical promises, the practical realities in Lagos State present a more complex picture. Many science classrooms, particularly in developing countries, continue to rely on traditional evaluation methods because of large class sizes, inadequate instructional resources, and varying levels of teachers' digital competence, which limit the implementation of technology-enhanced assessment (UNESCO, 2023; Ertmer & Ottenbreit-Leftwich, 2010; OECD, 2019).

The introduction of AI-based evaluation tools into such contexts raises critical questions about feasibility, accessibility, and effectiveness. Can these tools genuinely enhance teaching effectiveness, or do they risk becoming sophisticated instruments that are underutilised or misapplied? Are teachers equipped to interpret the data generated by these systems, or does the technology introduce a new layer of complexity that undermines its intended benefits?

The significance of teaching effectiveness in science education cannot be overstated. Science serves as the backbone of technological innovation and economic development, and the quality of science education directly influences a nation’s capacity for progress. In Lagos State, where educational demands are intensified by rapid urbanisation and population growth, the need for effective teaching is particularly acute. Teaching effectiveness, in this context, is not merely an academic concern but a socio-economic imperative. It determines the extent to which students acquire the skills and knowledge necessary to navigate and contribute to an increasingly complex world.

Analogies from established literature further illuminate the role of evaluation in teaching effectiveness. Black and Wiliam’s (2020) seminal work on formative assessment likens effective evaluation to a compass rather than a map; it does not prescribe a fixed route but provides direction, enabling teachers to navigate the uncertainties of the classroom. AI-based evaluation tools can be seen as an advanced compass, offering not only direction but also predictive insights about the terrain ahead. However, a compass is only useful if the navigator knows how to read it. This analogy underscores the importance of teacher competence and readiness in leveraging AI tools effectively.

Metaphorically, the integration of AI-based evaluation tools into science classrooms can be compared to introducing a microscope into a laboratory. Just as a microscope reveals details that are invisible to the naked eye, AI tools can uncover patterns in student learning that would otherwise remain hidden. Yet, the presence of a microscope does not guarantee scientific discovery; it requires skilled use and critical interpretation. Similarly, the effectiveness of AI-based evaluation tools depends on how they are integrated into pedagogical practices and how their outputs are utilised to inform teaching.

Emerging empirical studies provide preliminary evidence of the potential benefits of AI in educational evaluation. Research indicates that AI-driven assessment systems can improve the accuracy and consistency of grading, enhance the timeliness of feedback, and support personalised learning (Chen et al., 2022; Holmes et al., 2022). However, these studies also highlight challenges related to data privacy, algorithmic bias, and the need for professional development. In contexts like Lagos State, where infrastructural and institutional factors may differ significantly from those in developed countries, the transferability of these findings remains an open question.

The discourse, therefore, converges on a set of critical academic questions that underpin this study. To what extent do AI-based evaluation tools enhance teaching effectiveness in science classrooms within Lagos State? How do these tools influence the quality and timeliness of feedback provided to students? In what ways do they support or hinder teachers' ability to adapt their instructional strategies? What contextual factors mediate the relationship between AI-based evaluation and teaching effectiveness? These questions are not merely theoretical; they reflect the practical dilemmas faced by educators seeking to navigate the intersection of technology and pedagogy.

The rationale for this study is anchored in the need to move beyond anecdotal evidence and establish empirical insights into the effectiveness of AI-based evaluation tools in a specific educational context. While the global discourse on AI in education is expanding, there remains a paucity of context-specific studies that examine its impact within Nigerian classrooms. This study seeks to fill this gap by providing a nuanced understanding of how AI-based evaluation tools function within the realities of Lagos State's science education system.

In essence, this study positions AI-based evaluation tools not as a panacea but as a potentially powerful instrument within a broader pedagogical framework. Their effectiveness is contingent upon multiple factors, including teacher competence, institutional support, and the alignment of technology with educational objectives. The challenge, therefore, is not merely to adopt these tools but to integrate them thoughtfully and strategically, ensuring that they serve as catalysts for enhancing teaching effectiveness rather than as distractions or superficial innovations.

The background to this study thus establishes a compelling case for examining the effectiveness of AI-based evaluation tools in enhancing teaching effectiveness in science classrooms. It situates the research within a robust theoretical framework, highlights the practical challenges and opportunities, and articulates the critical questions that guide the investigation. In doing so, it sets the stage for a systematic exploration of how technology can be harnessed to improve the quality of science education in Lagos State, with implications that extend beyond the immediate context to the broader field of educational innovation.

Statement of the Problem

Teaching effectiveness in science classrooms in Lagos State continues to present measurable inconsistencies, particularly in the areas of timely feedback, instructional adaptation, and student conceptual understanding. Despite sustained pedagogical efforts, many science teachers rely on traditional evaluation approaches that are episodic, labour-intensive, and insufficiently diagnostic. These methods often delay feedback, obscure learning gaps, and limit opportunities for real-time instructional adjustment, thereby weakening the overall quality of teaching delivery. In an era where artificial intelligence has demonstrated the capacity to provide immediate, data-driven insights into learner performance, the limited integration of AI-based evaluation tools raises critical concerns about missed opportunities for pedagogical enhancement.

Empirical evidence suggests that effective feedback mechanisms significantly influence teaching quality and student learning outcomes (Wisniewski et al., 2020), yet conventional systems in many classrooms fail to meet this standard. AI-based evaluation tools, which utilise adaptive algorithms and analytics, offer a promising alternative by enabling continuous assessment and personalised feedback (Holmes et al., 2022). However, their effectiveness within the specific socio-educational context of Lagos State remains largely underexplored. This creates a knowledge gap regarding whether such tools can meaningfully enhance teaching effectiveness in science classrooms. Addressing this gap is essential for aligning instructional practices with contemporary technological advancements and improving educational outcomes.

Therefore, the purpose of this study was to examine the effectiveness of AI-based evaluation tools in enhancing teaching effectiveness in science classrooms in Lagos State, Nigeria. Specifically, from the teacher's point of view in science classrooms in Lagos State. the study examined the:

1. influence of AI-based evaluation tools on teachers’ instructional adaptability in science classrooms from the teacher's point of view.
2. influence of AI-based evaluation tools on overall teaching effectiveness in science classrooms from the teacher's point of view.

Hypotheses

Three null hypotheses were formulated and tested at .05 level of significance:

H_{01}: AI-based evaluation tools have no significant influence on the quality of feedback in science classrooms in Lagos State from the teacher's point of view.

H_{02}: AI-based evaluation tools have no significant influence on teachers’ instructional adaptability in science classrooms from the teacher's point of view.

H_{03}: AI-based evaluation tools have no significant influence on overall teaching effectiveness in science classrooms from the teacher's point of view.

Theoretical Underpinning

The Technological Pedagogical Content Knowledge (TPACK) theory provides a robust framework for understanding the integration of emerging technologies, such as AI-based evaluation tools, into teaching practice. The theory posits that effective teaching in contemporary classrooms requires a dynamic interplay between technological knowledge, pedagogical competence, and subject matter expertise (Mishra & Koehler, 2020). Within science education, this integration becomes particularly critical due to the abstract and cumulative nature of scientific knowledge.

AI-based evaluation tools align with the technological domain of TPACK by introducing advanced data analytics and adaptive feedback systems into classroom practice. However, their effectiveness is contingent upon how well teachers integrate these tools into pedagogical processes. Studies have shown that technology alone does not enhance teaching effectiveness unless it is meaningfully embedded within instructional strategies (Zawacki-Richter et al., 2021). This underscores the importance of teachers’ capacity to interpret AI-generated insights and translate them into actionable teaching interventions.

Furthermore, the feedback dimension within TPACK resonates with contemporary findings that emphasise the role of timely and specific feedback in improving learning outcomes (Wisniewski et al., 2020). AI-based tools enhance this dimension by providing immediate and personalised feedback, thereby strengthening the feedback loop that is central to effective teaching. In this sense, AI functions as an intellectual scaffold, supporting teachers in diagnosing learning gaps and adjusting instruction accordingly.

The relevance of TPACK to this study lies in its ability to conceptualise AI-based evaluation tools not as isolated innovations but as integral components of a holistic teaching framework. It provides a theoretical lens through which the relationship between technology use and teaching effectiveness can be systematically examined within science classrooms in Lagos State.

Methodology

The study employed a multistage sampling technique to select a total of 300 science teachers from secondary schools across Lagos State. In the first stage, the State was stratified into its educational districts to ensure geographical spread and inclusion of teachers from diverse administrative zones. Within each district, schools were further stratified into public and private categories to capture institutional diversity. In the second stage, a predetermined number of schools was selected from each stratum using simple random sampling, thereby giving every school an equal chance of inclusion. In the final stage, science teachers within the selected schools constituted the target group, and simple random sampling was again employed to select respondents proportionally to the size of the science staff in each school. This procedure ensured that the final sample of 300 respondents was representative of the broader population of science teachers in Lagos State.

Data were collected using a self-designed instrument titled *AI-Based Evaluation Tools and Teaching Effectiveness Questionnaire (AIETTEQ)*. The instrument consisted of structured items measured on a four-point Likert scale. To ensure validity, a pilot study was conducted with 30 science teachers outside the main sample, and expert reviews were obtained. The reliability of the instrument was established using Cronbach's alpha coefficient, which yielded a value of 0.87, indicating high internal consistency.

The data collection process was conducted through direct administration of questionnaires with the assistance of trained research aides. Ethical considerations, including informed consent and confidentiality, were strictly adhered to. Data analysis was carried out using descriptive statistics (mean and standard deviation) and inferential statistics, specifically multiple regression analysis, to test the three null hypotheses at a 0.05 level of significance.

Results

The demographic distribution indicates a balanced representation of respondents across gender, teaching experience, and subject specialisation. A higher proportion of participants possessed over ten years of teaching experience, suggesting that responses were largely drawn from seasoned professionals capable of evaluating instructional effectiveness critically. The dominance of public school teachers reflects the broader structure of Lagos State's education system. The distribution across science subjects ensures disciplinary diversity, enhancing the generalisability of findings. Overall, the dataset provides a credible foundation for examining the effectiveness of AI-based evaluation tools across varied instructional contexts and teacher competencies.

Hypothesis One

H_{01}: AI-based evaluation tools have no significant influence on the quality of feedback in science classrooms.

Table 2: Regression Analysis on AI-Based Evaluation Tools and Quality of Feedback

Item	Statement	Mean	Std. Dev	Beta	p-value
1	AI tools provide immediate feedback to students	3.48	0.62	0.71	0.000
2	AI enhances clarity of feedback	3.42	0.66	0.68	0.000
3	AI identifies student errors accurately	3.36	0.70	0.65	0.001
4	AI supports personalised feedback delivery	3.40	0.64	0.69	0.000
5	AI improves consistency in feedback	3.38	0.68	0.66	0.001

Decision Rule: Reject H_0 if $p < 0.05$. **Source: Field Report, 2026**

The results reveal statistically significant relationships between AI-based evaluation tools and feedback quality across all items, as perceived by the participants, with p-values well below the 0.05 threshold. The high beta coefficients indicate strong predictive influence, particularly in the immediacy and clarity of feedback. Respondents consistently rated AI tools above the midpoint, suggesting widespread agreement on their effectiveness. The findings imply that AI-based systems address key deficiencies in traditional feedback mechanisms by enhancing timeliness, precision, and personalisation. Consequently, the null hypothesis is rejected, confirming that AI-based evaluation tools significantly improve the quality of feedback in science classrooms.

Hypothesis Two

H_{02}: AI-based evaluation tools have no significant influence on teachers' instructional adaptability.

Table 3: Regression Analysis on AI-Based Tools and Instructional Adaptability

Item	Statement	Mean	Std. Dev	Beta	p-value
1	AI enables real-time instructional adjustments	3.44	0.65	0.69	0.000
2	AI supports differentiated instruction	3.39	0.67	0.66	0.001
3	AI improves lesson planning flexibility	3.35	0.69	0.64	0.002
4	AI helps identify learning gaps promptly	3.47	0.61	0.71	0.000
5	AI enhances responsiveness to student needs	3.41	0.66	0.68	0.001

Decision Rule: Reject H_0 if $p < 0.05$. **Source: Field Report, 2026**

The analysis demonstrates a statistically significant influence of AI-based evaluation tools on instructional adaptability, as perceived by the participants. All items recorded strong mean values and significant p-values, indicating that teachers perceive AI as a catalyst for responsive teaching. The highest impact is observed in identifying learning gaps, reinforcing the role of AI as a diagnostic instrument. These findings suggest that AI tools enable teachers to shift from rigid instructional patterns to more flexible, data-informed approaches. Consequently, the null hypothesis is rejected, affirming that AI-based evaluation tools significantly enhance teachers' ability to adapt instruction in science classrooms.

Hypothesis Three

H_{03}: AI-based evaluation tools have no significant influence on overall teaching effectiveness.

Table 4: Regression Analysis on AI-Based Tools and Teaching Effectiveness

Item	Statement	Mean	Std. Dev	Beta	p-value
1	AI improves overall teaching performance	3.46	0.63	0.70	0.000
2	AI enhances student engagement	3.38	0.68	0.66	0.001
3	AI supports achievement of learning objectives	3.42	0.65	0.68	0.000
4	AI increases instructional efficiency	3.40	0.66	0.67	0.001
5	AI promotes better learning outcomes	3.45	0.64	0.69	0.000

Decision Rule: Reject H_0 if $p < 0.05$. **Source: Field Report, 2026**

The findings indicate a strong and statistically significant impact of AI-based evaluation tools on teaching effectiveness. The consistently high mean scores and significant p-values demonstrate that AI contributes positively to multiple dimensions of teaching, including performance, engagement, and learning outcomes. The beta values suggest a robust predictive relationship, reinforcing the role of AI as an enhancer of instructional quality. These results confirm that AI-based tools are not merely supportive technologies but central drivers of effective teaching practices. The null hypothesis is therefore rejected.

Discussion

The findings revealed that participants were of the view that AI-based evaluation tools can significantly improve the quality of feedback, particularly in terms of immediacy, clarity, and personalisation. This aligns with Wisniewski et al. (2020), who established that timely and specific feedback enhances learning outcomes. Similarly, Holmes et al. (2022) found that AI-driven systems provide consistent and data-informed feedback that surpasses traditional methods. The present study's high beta coefficients reinforce these claims, demonstrating that AI tools function as precision instruments in feedback delivery. However, the findings contrast with Zawacki-Richter et al. (2021), who argued that which may limit the effectiveness of AI feedback. While this concern remains valid, the current data suggests that, within Lagos State, teachers are increasingly leveraging AI tools effectively, thereby minimising such limitations and enhancing overall feedback quality.

The study found that AI-based evaluation tools significantly influenced instructional adaptability, enabling teachers to adjust teaching strategies in real time. This finding corroborates Ifenthaler and Schumacher (2021), who emphasised that data-driven insights facilitate adaptive teaching practices. Additionally, Chen et al. (2022) reported that AI systems support differentiated instruction by identifying individual learning needs. The present findings extend this argument by demonstrating strong statistical relationships between AI use and instructional flexibility. Conversely, Selwyn (2020) cautioned that over-reliance on AI may reduce teachers' professional autonomy. While this concern highlights potential risks, the evidence from this study indicates that AI tools act as supportive aids rather than replacements, empowering teachers to make informed instructional decisions without undermining their expertise.

The results confirmed that AI-based evaluation tools significantly enhanced overall teaching effectiveness, including student engagement and learning outcomes. This aligns with Holmes et al. (2022), who highlighted the transformative potential of AI in improving instructional quality. Similarly, Chen et al. (2022) demonstrated that AI integration leads to measurable improvements in teaching performance. The strong beta values observed in this study reinforce these conclusions, suggesting that AI tools contribute to a more efficient and impactful teaching process. However, the findings diverge from Selwyn (2020), who argued that technological interventions may not always translate into improved educational outcomes due to contextual constraints. Despite this, the present study provides empirical evidence that, AI-based evaluation tools are effectively enhancing teaching effectiveness within Lagos State,.

Conclusion

The study revealed that, in the respondents' view, AI-based evaluation tools exerted a statistically significant and positive influence on key dimensions of teaching effectiveness in science classrooms across Lagos State. Teachers perceived that these tools substantially enhanced the quality of feedback, a perception supported by strong beta values ranging from 0.65 to 0.71 and highly significant p-values below 0.05. From their standpoint, AI-driven systems addressed long-standing challenges associated with delayed and generic feedback in traditional instructional settings, thereby offering more timely and tailored support for teaching. The results confirmed that AI-based evaluation tools enhanced instructional adaptability, enabling teachers to respond dynamically to learners' needs. The consistently high mean scores and significant regression outcomes suggest that teachers are increasingly leveraging AI-generated insights to refine their pedagogical strategies. In addition, the study revealed a robust impact on overall teaching effectiveness, with beta values between 0.66 and 0.70, indicating that AI tools contribute meaningfully to improved teaching performance, student engagement, and learning outcomes.

Taken together, the findings position AI-based evaluation tools not merely as supportive technologies but as strategic enablers of effective teaching. Their integration into science classrooms represents a critical step towards achieving data-driven, responsive, and outcome-oriented instructional practices within the Lagos State education system.

Recommendations

The findings of this study highlight the practical relevance of AI-based evaluation tools in transforming instructional delivery. However, effective implementation requires deliberate policy, capacity-building, and infrastructural support. Based on the empirical evidence, the following recommendations are proposed:

1. Educational authorities should institutionalise the integration of AI-based evaluation tools into science teaching frameworks to enhance feedback quality and instructional precision.
2. Continuous professional development programmes should be organised to equip teachers with the technical and pedagogical competencies required to utilise AI tools effectively.
3. Schools should invest in digital infrastructure to ensure seamless deployment and accessibility of AI-based evaluation systems across classrooms.
4. Curriculum planners should embed AI-driven assessment strategies into science education policies to promote adaptive and learner-centred teaching practices.
5. Monitoring and evaluation mechanisms should be established to assess the long-term impact of AI-based tools on teaching effectiveness and student learning outcomes.

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