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Digital Literacy, Test Anxiety, and Achievement in STEM Examinations: A Comparative Study of Computer-Based Testing and Traditional Paper-Based Assessment

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Abstract
Assessment plays a pivotal role in evaluating learning outcomes in science, technology, engineering, and mathematics (STEM) education, where conceptual understanding and problem-solving skills are critical. With the growing adoption of digital technologies, computer-based testing (CBT) has emerged alongside traditional written (paper-based) examinations, prompting debates about their comparative effectiveness. This study investigates the impact of both formats on academic performance, cognitive engagement, test anxiety, and student perceptions in Nigerian tertiary institutions. Adopting a mixed-method design, quantitative performance and perception data were complemented by qualitative insights from focus groups. Findings revealed that written examination participants achieved marginally higher scores (M = 71.3) than their CBT counterparts (M = 68.5), with the difference reaching statistical significance (p = 0.006). While CBT offered efficiency and rapid feedback, it was associated with higher anxiety levels and limitations in assessing complex reasoning. Written examinations, by contrast, better supported extended responses, graphical representation, and multi-step problem solving. The study recommends a balanced, context-sensitive assessment strategy that integrates both formats to harness their respective strengths, improve equity, and optimize learning outcomes in STEM disciplines.

Keywords: Computer-Based Testing, STEM Education, Digital Literacy, Assessment Format, Mixed-Method Research

Introduction

Assessment is a core component of modern education, functioning not only as a means of evaluating student learning but also as a driver of instructional design, pedagogical improvement, and learner engagement (Brown, 2019). This is particularly true in STEM (science, technology, engineering, and mathematics) education, where success relies heavily on analytical reasoning, critical thinking, and problem-solving abilities (Alo et al., 2021). Paper-based examinations have been the dominant mode of assessment across educational systems (Drasgow, 2002). The rapid integration of digital technologies has led to the rise of computer-based testing (CBT) as a credible alternative. As of 2024, digital assessments have evolved to include adaptive testing models, AI-driven feedback, and tools for assessing twenty-first-century competencies such as digital literacy and complex problem-solving (ExaminationRoom.ai, 2025; MinervaInfo, 2024; Watermark Insights, 2024). These innovations have transformed assessment practices globally by offering immediate feedback, operational efficiency, and enhanced scalability. In Nigeria, examination bodies such as the Joint Admissions and Matriculation Board (JAMB) and several tertiary institutions have adopted CBT for both entrance and internal assessments, aligning with broader national strategies for integrating information technology into education (Alo et al., 2021).

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Theoretical Perspectives Guiding STEM Assessment

Theories of learning provide valuable frameworks for evaluating the effectiveness of assessment formats in STEM education. Constructivist perspectives (Piaget, 1952; Vygotsky, 1978) emphasize that learning is an active process of constructing knowledge rather than passively receiving information. In this view, effective STEM assessment must go beyond recall, requiring tasks that prompt analytical thinking, application of concepts, and integration of knowledge across contexts. While CBT research often highlights operational benefits such as speed and automation, fewer studies interrogate whether current CBT platforms facilitate the deep, reflective engagement necessary for STEM mastery.

Cognitive Load Theory by Sweller in 1988 also offers critical insight. Digital assessments can impose additional extraneous load through interface navigation, scrolling, and screen fatigue—factors that may compete with the cognitive demands of solving multi-step STEM problems. Yet, many comparative studies of CBT and written examinations overlook how such factors may disproportionately affect complex tasks involving symbolic manipulation, extended reasoning, or graphical interpretation. These omissions limit understanding of whether digital delivery hinders or enhances the demonstration of higher-order skills in STEM contexts.

Computer-Based Testing: Advantages and STEM-Specific Challenges

CBT—defined as assessment delivered through digital platforms (Dan'Inna & Ihekwaba, 2024; Marks, 2007)—offers notable benefits including automated scoring (Wahyuningrum et al., 2024), immediate feedback (Ejim, 2018; Parvathy et al., 2025), randomized item sequencing (Huda et al., 2024), and flexible design features (Burns, 2022; Egoigwe et al., 2020; Izevbizua et al., 2024). In Nigeria, the adoption of CBT by JAMB has been credited with reducing malpractice and improving result turnaround times (Alo et al., 2021; Ikechukwu et al., 2017). Multimedia integration and simulations also offer the potential to enrich STEM assessment by visualizing abstract concepts and fostering engagement. However, much of the literature on CBT in STEM remains aspirational rather than evidential. While potential benefits are recognized, fewer studies demonstrate that CBT effectively captures competencies such as extended problem-solving, conceptual reasoning, or the articulation of solution steps. Documented challenges ranging from heightened anxiety among students with limited digital exposure (Bennett, 2015) to infrastructural limitations (Bolanta, 2024; Crane et al., 2021; Usman & Olaleye, 2022) and irregular power supply (Dwiyono et al., 2021), are well known, but STEM-specific implications are rarely explored. For example, the inability of some CBT systems to handle symbolic notation, freehand diagrams, or multi-stage calculations directly constrains their capacity to assess the full range of STEM learning outcomes. Students with special needs face additional, under-researched barriers in digital assessment environments (Reaven et al., 2022).

Paper-Based Examinations: Strengths and Limitations

Paper-based examinations remain a reliable means of assessing both lower- and higher-order cognitive skills (Adigun et al., 2021). In STEM disciplines, their affordance for detailed workings, diagrams, and organized extended responses is particularly valuable. Such formats allow students to demonstrate their reasoning processes, critical for evaluating problem-solving strategies and conceptual depth. Nonetheless, tpaper-based examinations have inefficiencies including delayed feedback, labor-intensive marking, and susceptibility to human error (Usman & Olaleye, 2022). Their lack of digital integration may also hinder the development of digital literacy, a competency increasingly vital in the STEM workforce. While these trade-offs are acknowledged, there is limited empirical work linking the manual nature of paper-based assessment to specific learning trajectories or skill development in STEM contexts.

Comparative Studies: Mixed Evidence and Methodological Shortcomings

Empirical comparisons of CBT and written examinations report inconsistent findings. Some studies detect no significant performance difference when content and difficulty are equivalent (Clariana & Wallace, 2002), whereas others note that student familiarity, test anxiety, and content type influence outcomes (Adigun et al., 2021; Khan & Fareed, 2021). A key limitation is the tendency to report aggregate scores without disaggregating by question type, i.e. calculation-based, conceptual explanation, or diagrammatic tasks. This masks format-specific advantages or disadvantages in assessing particular STEM competencies. Similarly, few studies explore how preparation strategies differ between formats and how these differences interact with content demands in STEM fields.

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Student Perceptions and Preferences: A Diagnostic Lens

Student perceptions significantly shape test performance through their influence on anxiety, motivation, and preparation strategies (Ebrahimi et al., 2019). CBT is often valued for speed and clarity of results but criticized for time constraints on extended responses and difficulties with graphical interpretation. Conversely, written examinations are preferred for tasks requiring elaborate reasoning and slower, self-paced completion (Adigun et al., 2021). However, perceptions are rarely used diagnostically to improve assessment design. For instance, if students report difficulty interpreting diagrams on screen, this suggests an interface design issue that could be addressed. Likewise, if "simpler" CBT questions raise confidence but potentially reduce cognitive demand, this warrants scrutiny of test validity in STEM contexts.

Challenges in CBT Implementation: Beyond Descriptive Accounts

Barriers such as unstable internet, inadequate ICT facilities, power supply disruptions, and limited technical support are frequently cited (Adigun et al., 2021; Alo et al., 2021; Usman & Olaleye, 2022). Yet most discussions stop short of connecting these directly to STEM-specific outcomes. Poorly optimized platforms may, for example, distort the rendering of equations or graphs, thereby undermining assessment validity for subjects like mathematics or physics. Similarly, insufficient examiner training in digital assessment design can lead to poorly constructed STEM items, compounding measurement issues.

Towards an Integrated Assessment Approach

The literature increasingly recommends combining CBT and paper-based formats to maximize validity, equity, and pedagogical relevance (Adigun et al., 2021). However, most calls for blended assessment remain high-level, offering limited practical guidance. An effective STEM-focused model would need to address infrastructure gaps, train students and teachers in digital tools, and allocate question types to the format best suited for them—extended problem-solving on paper, objective items in CBT, and multimedia-supported tasks in digital environments. This study builds on these gaps by critically evaluating the performance, perceptions, and engagement outcomes associated with both assessment formats in STEM education, while also proposing practical steps for integrating their respective strengths.

Statement of the Problem

The increasing adoption of computer-based testing (CBT) in Nigerian tertiary institutions has transformed assessment practices in STEM education. While CBT is valued for its efficiency and administrative advantages, concerns persist regarding its effectiveness in assessing STEM learning outcomes that require extended reasoning, problem-solving, and graphical representation. Evidence from existing studies comparing CBT and paper-based examinations remains inconsistent, with limited attention given to learner-related factors that may influence performance across assessment formats. In particular, the moderating roles of digital literacy and gender in shaping achievement outcomes are not sufficiently established, despite their relevance in digitally mediated assessments. Moreover, student engagement and perceptions of assessment formats, actors closely associated with test anxiety and performance, are often underexplored in comparative assessment studies. In contexts characterized by unequal access to digital resources and varying levels of technological competence, these gaps raise concerns about the fairness and validity of CBT for STEM assessment. There is therefore a need for empirical evidence that systematically examines the effects of assessment format on STEM achievement, engagement, and perceptions, while accounting for key moderating variables within Nigerian Colleges of Education.

Aim and Objectives of the Study

The aim of the study was to investigate digital literacy, test anxiety, and achievement in stem examinations: a comparative study of computer-based testing and traditional paper-based assessment. Specific objectives were to:

1. Determine whether there is a significant difference in STEM learning outcomes between students assessed through CBT and those assessed through paper-based examinations.
2. Examine whether gender moderates the relationship between assessment format and student achievement.
3. Assess whether digital literacy levels moderate the relationship between assessment format and student achievement.
4. Explore how assessment format influences student engagement in STEM education.
5. Identify differences in student perceptions of CBT and written examinations.
6. Provide evidence-based recommendations for improving assessment practices in STEM education.

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Research Questions

1. Is there a significant difference in STEM achievement between students assessed via CBT and those assessed via written examinations?
2. Does gender moderate the effect of assessment format on STEM achievement?
3. Do digital literacy levels moderate the effect of assessment format on STEM achievement?
4. How does assessment format influence student engagement in STEM education?
5. How do students' perceptions differ between CBT and written examinations?
6. What guidance can be derived from the findings for improving STEM assessment practices?

Hypotheses

$H0_1$: There is no significant difference in STEM achievement between students assessed via CBT and those assessed via written examinations.
$H0_2$: Gender does not significantly moderate the relationship between assessment format and STEM achievement.
$H0_3$: Digital literacy levels do not significantly moderate the relationship between assessment format and STEM achievement.

Methods and Materials

Research Design

This study employed a comparative mixed-method design to examine the impact of different assessment formats (computer-based testing and paper-based examinations) on STEM learning outcomes, student engagement, and perceptions. This approach allowed for the triangulation of quantitative data on student performance and perceptions with rich qualitative insights into their experiences.

Participants

The study population comprised final-year Integrated Science students, whose major subjects are STEM-related courses (Physics, Chemistry, Biology, and Mathematics) across three public colleges of education in Kwara State, Nigeria. A total of 287 students were randomly sampled and assigned to two groups: one assessed via CBT (n = 143) and the other via a paper-based examination (n = 144).

Instruments

Three primary instruments were utilized: the STEM Performance Test (SPT), the Assessment Experience and Perception Questionnaire (AEPQ), and the Digital Literacy Assessment (DLA). The STEM Performance Test was a 40-item test designed to assess core STEM concepts, with a particular focus on capturing a comprehensive range of cognitive skills relevant to STEM, including problem-solving and higher-order thinking. To achieve this, the SPT was originally developed to include multiple-choice, short-answer, and problem-solving items. For the multiple-choice items, specific attention was paid to designing questions that went beyond rote memorization, incorporating strategies such as:

1. **Scenario-Based Questions:** Presenting short STEM-relevant scenarios or case studies requiring analysis and application of principles to arrive at the best solution among the options.
2. **Integration of Visuals and Data:** Utilizing diagrams, charts, graphs, or data tables, with questions requiring students to interpret, analyze, or predict based on the visual information.
3. **Multi-Step Problems:** Designing questions that necessitate the synthesis and application of multiple STEM concepts or steps to derive the correct multiple-choice answer.
4. **"Best Answer" with Implicit Justification:** Crafting options where students must select the most appropriate answer based on a deeper understanding of underlying principles, implying a reasoning process.

To ensure content validity for all item types, the SPT underwent rigorous expert review by experienced STEM educators and measurement and evaluation experts. Reliability analysis yielded a Cronbach's alpha of 0.84, indicating strong internal consistency.

The Assessment Experience and Perception Questionnaire was a 20-item Likert-scale questionnaire developed to capture students' perceptions of ease of use, fairness, anxiety levels, and the perceived effectiveness of each assessment format. The instrument was validated through pilot testing and expert review, achieving a reliability coefficient of 0.88. The Digital Literacy Assessment was a 15-item instrument, combining a practical assessment

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with a self-report questionnaire, used to measure students' digital proficiency. The practical component evaluated foundational computer skills (e.g., file management, basic software navigation, and operating within simulated online test environments using common input methods like keyboard and mouse). The self-report section gathered data on students' confidence in using digital tools for academic purposes and their frequency of engagement with these tools. The DLA underwent pilot testing and a reliability analysis, yielding a Cronbach's alpha of 0.81 for the self-report component and demonstrating strong inter-rater reliability for the practical assessment, ensuring its consistency and accuracy in measuring digital literacy. This detailed assessment of digital literacy allowed us to better account for its potential influence on CBT performance. Focus Group Discussions (FGDs) were conducted with a subset of 24 participants (12 from each assessment group) to gain rich qualitative insights into their experiences, preferences, and suggestions for improving assessment practices with both assessment types.

Procedure

The study spanned a 6-week period. Students in both groups received instruction on the same STEM topics using identical methods and materials. Following instruction, each group was assessed using their designated format (CBT or written examination) under strict examination conditions, proctored by trained staff. Subsequently, students completed the AEPQ anonymously. FGDs were then held with selected students.

Data Analysis

Quantitative data from the SPT were analyzed using both descriptive and inferential statistics. Means and standard deviations summarized student performance. Independent samples *t*-tests determined significant differences between groups. Analysis of variance (ANOVA) explored how performance interacted with gender and digital literacy levels. For AEPQ data, percentages and mean scores were used to understand student attitudes. Qualitative responses from FGDs were transcribed verbatim and subjected to thematic analysis to identify recurring trends, patterns, and salient themes related to student assessment experiences and preferences, providing a deeper, nuanced understanding.

Ethical Considerations

All participants were fully informed about the purpose and procedures of the study before taking part, and written consent was obtained from each of them. Participation was voluntary, and students were assured that they could withdraw at any stage without any consequences for their academic standing. The study did not expose participants to any form of physical or psychological harm, as all activities involved normal classroom learning and standard assessment procedures. Confidentiality was strictly maintained throughout the study. No identifying information was collected, and all responses were coded and anonymized during analysis and reporting. The research posed minimal risk and had potential benefits for participants, as the findings may contribute to improving assessment practices in their institutions and enhancing the fairness, effectiveness, and overall learning experience in STEM courses.

Results

This study examined the influence of assessment format (computer-based testing versus paper-based examinations) on STEM learning outcomes, student engagement, and perceptions among final-year Integrated Science students in three Nigerian Colleges of Education.

Table 1: Descriptive Statistics for SPT Scores by Assessment Format.

Assessment Format	N	M	SD
CBT	143	68.5	9.2
Written Examination	144	71.3	8.8

Table 1 shows that students who took the written examination scored higher on the STEM Performance Test (M = 71.3, SD = 8.8) compared to those assessed through CBT (M = 68.5, SD = 9.2). Although the difference in mean scores is not very large, it suggests that students may have found the written format more suitable for demonstrating their understanding of STEM concepts. This pattern aligns with the structure of written examinations, which allow students to show detailed workings, draw diagrams, and pace themselves more comfortably.

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Table 2: Independent Samples t-test for SPT Scores by Assessment Format.

Assessment Format	N	M	SD	t	df	p
CBT	143	68.5	9.2			
				2.78	285	.006
Written Examination	144	71.3	8.8			

The t-test result (t(285) = 2.78, p = .006) indicates that students assessed through the written examination performed significantly better than their CBT counterparts. This underscores the possibility that the written format enabled richer demonstration of STEM-related cognitive processes.

Table 3: ANOVA for SPT Scores by Assessment Format and Gender.

Source	*SS*	*df*	*MS*	*F*	*p*
Assessment Format	648.7	1	648.7	8.12	.005
Gender	102.5	1	102.5	1.28	.259
Assessment Format × Gender	70.3	1	70.3	0.88	.349
Error	22756.0	283	80.4		
Total	23577.5	286			

Specifically, assessment format significantly affected performance ($F_{(1, 283)} = 8.12$, $p = .005$), but gender did not ($F_{(1, 283)} = 1.28$, $p = .259$). The interaction effect ($F_{(1, 283)} = 0.88$, $p = .349$) was also not significant. This means the observed performance advantage of the written examination format was consistent for both male and female students.

Table 4: ANOVA for SPT Scores by Assessment Format and Digital Literacy Level,

Source	SS	df	MS	F	p
Assessment Format	652.8	1	652.8	8.21	.004
Digital Literacy Level	1245.9	2	622.9	7.84	< .001
Assessment Format × Digital Literacy	659.4	2	329.7	4.15	.016
Error	22320.0	281	79.4		
Total	23577.5	286			

The ANOVA shows significant main effects for assessment format (F(1, 281) = 8.21, p = .004) and digital literacy level (F(2, 281) = 7.84, p < .001), as well as a significant interaction effect (F(2, 281) = 4.15, p = .016). This indicates that the influence of assessment format on performance depends on students' digital literacy levels.

Post-hoc analysis

Because the ANOVA revealed a significant main effect of digital literacy, a post-hoc comparison using the Tukey HSD test was conducted. Results showed that students with high digital literacy scored significantly higher than both the moderate- and low-literacy groups ($p < .05$), while students with moderate literacy also outperformed those with low literacy ($p < .05$). To further explain the significant interaction between assessment format and digital literacy, simple main-effects analyses were performed. These revealed that among students with high digital literacy, performance did not differ significantly between the CBT ($M = 74.1$, $SD = 7.5$) and written examination groups ($M = 75.5$, $SD = 7.0$) ($p = .312$). However, among students with moderate digital literacy, those in the written examination group performed significantly better ($M = 69.8$, $SD = 8.2$) than those in the CBT group ($M = 65.2$, $SD = 8.9$) ($p = .021$). A similar pattern emerged for low literacy students, with written exam participants ($M = 67.5$, $SD = 9.0$) outperforming their CBT counterparts ($M = 61.5$, $SD = 9.5$) ($p = .008$). These

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results demonstrate that the performance disadvantage associated with CBT is concentrated among students with low to moderate digital literacy, whereas digitally proficient students perform similarly across both formats.

Influence on Student Engagement

Qualitative data from Focus Group Discussions (FGDs) provided insights into how students perceived engagement with STEM content across formats. Students largely perceived written examinations as fostering deeper engagement with the problem-solving process in STEM. Participants emphasized the importance of being able to "show all workings" and freely draw diagrams, which they viewed as crucial for demonstrating problem-solving and conceptual reasoning. This contrasted with perceived limitations in CBT for articulating detailed solutions or manipulating scientific symbols, as students reported difficulties inputting complex mathematical equations or scientific symbols. The sentiment that CBT questions were sometimes "too objective" or "simplified" suggested that this format, in its current form, might inadvertently promote a more superficial approach to understanding rather than true depth. Conversely, the ability to articulate detailed reasoning and have comfortable pacing in written examinations was a preferred aspect for students.

Differences in Student Perceptions

Quantitative perception data from the AEPQ (Table 5) showed written exams were rated slightly higher for ease of use (84% vs. 78%), fairness (80% vs. 76%), and perceived effectiveness (82% vs. 74%). CBT, however, was associated with higher reported anxiety ($M = 3.1$) than written exams ($M = 2.5$). Concerns about time constraints for extended responses (82%) and difficulty interpreting graphical data (76%) were more pronounced in CBT.

Table 5: Mean Scores and Percentages for AEPQ by Assessment Format.

Perception Category	CBT (*M*/%)	Written Examination (*M*/%)
Ease of Use	3.9/78%	4.2/84%
Fairness	3.8/76%	4.0/80%
Anxiety Levels	3.1/62% (high)	2.5/50% (moderate)
Perceived Effectiveness	3.7/74%	4.1/82%
Time Constraints (Concern)	4.1/82%	2.9/58%
Graphical Data Interpretation	3.8/76%	2.2/44%

FGD narratives reinforced these findings:

1. **Comfort and Familiarity with Written Examinations:** Many students expressed a strong preference for written examinations due to their familiarity and the comfort of physically writing out answers. Participants highlighted the ability to "show all workings" and draw diagrams freely as crucial for STEM subjects.
2. **CBT-Induced Anxiety and Technical Challenges:** A recurring theme was increased anxiety when taking CBT, stemming from fears of technical glitches, network failures, and pressure from the on-screen timer. Students also reported difficulties with the user interface, particularly concerning inputting complex mathematical equations or manipulating scientific symbols.
3. **Perceived Limitations of CBT for Higher-Order STEM Skills:** Participants frequently articulated that CBT, as currently implemented, did not adequately assess their deeper understanding or problem-solving abilities in STEM. They felt that CBT questions were often "too objective" or "simplified," failing to capture the nuances of their reasoning.
4. **Advantages of CBT: Rapid Feedback with Notable Constraint:** Despite the challenges, students acknowledged some benefits of CBT, primarily the immediate release of results and the speed of the examination process. However, the feedback provided was often limited to correct/incorrect answers without sufficient explanation for STEM problems, even though immediate feedback is a documented advantage of CBT.
5. **The Role of Digital Literacy and Infrastructure:** Students with higher self-reported digital literacy expressed less anxiety and more adaptability to CBT. However, infrastructural limitations such as unstable internet connectivity and power outages during mock tests were significant frustrations.

Evidence-Based Guidance for Improving Assessment Practices

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Insights for improving assessment practices emerged from the comprehensive analysis of performance, perceptions, and student suggestions during FGDs. Students expressed a strong desire for a "blended approach," proposing that complex, problem-solving questions requiring detailed workings or diagrams be administered on paper, while objective questions suitable for immediate feedback could use CBT. They also emphasized the critical need for comprehensive training on CBT platforms, including practical sessions specific to inputting STEM responses and familiarization with the digital testing environment. The identified challenges regarding technical issues, digital literacy disparities, and CBT's perceived inadequacy for higher-order STEM skills underscore the need for targeted design improvements and strategic implementation. The findings suggest that crucial steps include improving infrastructure, developing more robust and STEM-friendly CBT software, and providing adequate digital literacy training to optimize assessment practices. Thoughtful digital assessment implementation, especially when integrated with learner-centered strategies, can foster critical thinking and enhance cognitive engagement.

Discussion

The results of this study highlight clear differences in how students performed under the two assessment formats. Students who took the written examination scored higher than those assessed through CBT, especially among learners with low or moderate digital literacy. This suggests that the written format allowed students to express their reasoning more fully, particularly when responding to questions requiring calculations, diagrams, or several steps of explanation. Similar observations have been reported in earlier work showing that written examinations often support deeper reasoning in STEM subjects (Adigun et al., 2021).

Digital literacy emerged as an important factor. Students with strong digital skills performed similarly in both formats, but those with lower skills struggled more with CBT. This finding aligns with Cognitive Load Theory, which explains that when students have to spend effort navigating a digital interface, less cognitive capacity is available for performing complex tasks (Sweller, 1988). Reports from the focus group discussions reinforce this interpretation. Students described the CBT environment as stressful due to the on-screen timer, fear of technical issues, and difficulty entering symbols, equations, or diagrams. These experiences mirror earlier findings that test anxiety and unfamiliarity with digital tools can hinder performance in digital assessments (Bennett, 2015).

Students also raised concerns about the types of questions presented in CBT. Many described them as highly objective or simplified, making it difficult to show working or explain reasoning. Written examinations, in contrast, provided space to organise solutions and draw diagrams, likely contributing to the higher scores observed. Although CBT is widely recognised for benefits such as efficiency, reduced administrative burden, and rapid feedback (Ejim, 2018; Alo et al., 2021; Huda et al., 2024), the present study suggests that these advantages do not fully compensate for the challenges students face when solving STEM problems on a computer. This supports earlier warnings that digital assessments may compromise validity when they do not allow full expression of problem-solving processes (Drasgow, 2002).

Students acknowledged some strengths of CBT but preferred a blended approach in which objective items are delivered digitally while extended problem-solving tasks remain on paper. Taken together, the findings indicate that while CBT has value, it still requires improvements in platform design, digital literacy training, and infrastructure before it can function as a fair and comprehensive tool for STEM assessment in this context. Until those issues are addressed, written examinations appear better suited for capturing detailed STEM reasoning.

Conclusion

This study examined how computer-based testing and paper-based examinations influence STEM achievement, student perceptions, and engagement among final-year Integrated Science students in Colleges of Education. The findings show that written examinations resulted in higher performance, particularly for students with low to moderate digital literacy. Students with stronger digital skills performed similarly across both formats, highlighting the crucial role of digital competence in moderating CBT outcomes. This pattern reflects the effect of cognitive load, where unfamiliar digital environments can impose additional demands that hinder problem-solving in STEM tasks (Sweller, 1988). Qualitative data further explained these differences. Students reported that the written format allowed them to show all workings, draw diagrams, and organise extended responses, while the CBT interface limited these abilities and increased anxiety. Although CBT was appreciated for its speed and efficiency (Ejim, 2018; Alo et al., 2021), these benefits did not outweigh the challenges students encountered when completing complex STEM questions digitally. The study suggests that CBT, in its current form in the

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participating institutions, is not yet capable of assessing the full range of STEM competencies fairly and effectively. Improving digital literacy, upgrading CBT platforms to better support symbolic and diagram-based input, and strengthening infrastructure are essential steps for future implementation. Until these gaps are addressed, written examinations remain the more reliable format for evaluating detailed STEM reasoning and problem-solving.

Recommendations

The results of this study point to several practical steps that institutions and educators can take to strengthen assessment practices in STEM courses.

1. Paper-based examinations should be used for STEM tasks that involve extended problem solving. This format gives students more room to explain their ideas clearly, and this advantage was observed for both male and female students
2. Colleges of education should provide systematic digital literacy training before major CBT assessments. Such training should include hands-on practice with navigation, item response procedures, and the use of digital tools relevant to STEM tasks.
3. Improving ICT infrastructure, ensuring reliable power supply, and offering trial tests before high-stakes examinations would help reduce this anxiety and improve students' confidence when using CBT platforms.
4. Examination bodies and software developers should therefore enhance CBT platforms to accommodate symbolic reasoning, freehand sketches, and multi-step calculations so that the digital format can better reflect the cognitive demands of STEM subjects.
5. Objective questions that require rapid scoring can be delivered through CBT, while complex, reasoning-based tasks can be assessed on paper. This approach would allow each format to be used where it is most effective.
6. Ongoing student feedback should be incorporated into assessment planning. The perceptions gathered in this study, particularly regarding fairness; usability; and preferred formats, underscore the value of engaging students in discussions about examination design. Regular feedback mechanisms can help institutions identify emerging challenges early and refine their assessment practices over time.

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