

# Effectiveness of Digital Assessment in Measuring Science Learning Outcomes in HEIs in Nigeria: A Case Study of the University of Delta, Agbor.

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## Research Article

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# Abstract

This study investigates the effectiveness and operational challenges associated with utilizing digital assessment tools for measuring science learning outcomes within Higher Education Institutions (HEIs) in Nigeria, focusing specifically on the University of Delta, Agbor. Adopting a robust sequential explanatory mixed-methods design, the research combined both quantitative and qualitative approaches to provide a nuanced understanding of digital assessment's impact on STEM learning. Quantitative data were analyzed using IBM SPSS version 27.0.1, employing descriptive statistics (frequencies and percentages) to outline trends, and inferential statistics (Independent t-tests, ANOVA, and ANCOVA) to test hypotheses and explore interaction effects among variables. The findings reveal a strong desire for technological integration, with 63.4% of respondents expressing support for the full adoption of digital assessment. This willingness persists despite widespread operational hurdles; a significant 75.2% of participants reported experiencing technical problems "sometimes" (63.2%) or "often" (12.0%). The study, which was predominantly informed by student perspectives (95.2% student respondents vs. 3.2% faculty staff), identified that the primary barriers to effective implementation are systemic. Specifically, infrastructure inadequacy was cited as the biggest problem by 78.5% of respondents, followed by insufficient training needs (53.7%). The study concludes that while the necessary user acceptance and drive for digital transformation exist, the current capacity to effectively leverage digital assessment for measuring learning outcomes is critically hindered by fundamental deficits in institutional infrastructure and essential user training. Recommendations center on urgent strategic investment in technological infrastructure and targeted professional development to bridge the gap between user enthusiasm and technological capability.

## 1. INTRODUCTION

The 21st century world is defined as the technology era where every domain and activity is shaped by technology. This evolution has not spared the higher education systems especially in development of digital assessment as a transformative tool for measuring student learning outcomes. The shift from traditional paper-based examinations to digital assessment methods is driven by the need for efficient, flexible and scalable evaluation systems. In the domain of science education, where problem-solving, critical thinking, and hands-on application of knowledge are crucial, the effectiveness of digital assessment is particularly significant. The adoption of digital assessment methods in Nigerian higher education institutions (HEIs) represents an effort to align with global best practices, improve evaluation of learning, and ensuring the reliability of academic performance metrics.

Science education systems in Nigeria have been faulted for its numerous challenges, including inadequate infrastructure, outdated curricula, poor practical/ hands-on experience and a lack of innovative assessment strategies (Akpoguma & Egboro, 2024). Traditional assessment methods have often been accused of failing to capture students' ability to apply theoretical knowledge to real-world problems, a core learning outcome in science and technology disciplines ((Ghosh et al., 2020; Sutadji et al., 2021). Digital assessment, through tools such as computer-based testing (CBT), interactive

simulations, and online formative assessments, offers a more dynamic and comprehensive evaluation framework with effective feedback (Price et al., 2022). However, despite the growing implementation of digital assessment in Nigerian universities, concerns persist regarding its effectiveness in accurately measuring learning outcomes, particularly in science and technology fields where hands-on experimentation and applied problem-solving are essential.

The University of Delta, Agbor, adopted this digital assessment and has been an advocate of digital transition, integrating various digital assessment tools to evaluate student performance across disciplines, including science and technology programs. However, the effectiveness of these assessments in accurately reflecting students' learning outcomes remains an area of scholarly debate needing inquiry. Are digital assessments adequately capturing students' competencies? Do they enhance or hinder academic performance in STEM-related courses? How do students and faculty perceive the impact of digital assessments on learning quality? These questions necessitate an empirical investigation into the effectiveness of digital assessment in Nigerian HEIs. Using University of Delta as a case in point, this study seeks to evaluate the effectiveness of digital assessment in measuring learning outcomes with a specific focus on science disciplines. By analyzing the benefits, challenges, and overall impact of digital assessment on student learning, this research aims to provide insights that will justify or otherwise the use of digital assessment and inform policy recommendations on digital assessment in Nigerian HEIs.

### **Concept of Digital Assessment in Higher Education**

Assessment is a fundamental aspect of the learning process, providing insight into students' knowledge acquisition, skill development, and overall academic progress. Digital assessment refers to the use of technology-based tools and platforms to evaluate student learning, replacing or supplementing traditional paper-based assessments (Awidi & Paynter, 2024; Zhu, 2024; Csapó et al., 2011). This approach is gaining traction due to its ease and potential for real-time feedback on learning outcomes and personalized assessment methods (Blundell, 2021; Zhu et al., 2023; Safitri & Purnamasari, 2024). These digital tools include computer-based testing (CBT), online quizzes, e-portfolios, automated grading systems, and simulation-based assessments. The transition to digital assessment in higher education institutions is driven by the need for efficiency, scalability, and enhanced accessibility in measuring student performance (Redecker & Johannessen, 2013). In the context of STEM education, digital assessment offers opportunities for interactive learning, real-time feedback, and adaptive testing. However, concerns regarding the effectiveness of digital assessment in accurately capturing students' cognitive abilities, critical thinking skills, and hands-on competencies remain persistent (Gikandi, Morrow, & Davis, 2011).

While existing literature highlights the benefits and challenges of digital assessment, there is limited research on its effectiveness in measuring learning outcomes in STEM disciplines within Nigerian HEIs. Specifically, there is no clear understanding founded on empirical evidence on the impact of digital assessment on STEM student performance in Nigerian universities. There is also limited research on

students' and lecturers' perceptions of digital assessment in STEM courses as well as deficit of information on digital assessment strategies that effectively measure problem-solving and critical thinking skills. Further studies on the impact of digital assessment infrastructure and policies on learning outcomes in Nigerian HEIs is needed to provide evidence-based insights into the effectiveness of digital assessment in measuring learning outcomes in STEM education at the University of Delta, Agbor and by extension, HEIs in Nigeria.

## **Theoretical Framework and Analysis**

Several theoretical perspectives underpin the adoption of digital assessment in higher education. These frameworks provide insights into how students and educators interact with digital tools, the psychological and pedagogical basis for digital assessment as well as the designing of digital tools for effective learning outcome assessment. Piaget's (1956) strand of constructivism conceptualizes learning as an active process in which learners construct knowledge through experience and interaction with their environment. Constructivist Learning Theory (Piaget, 1970) suggests that students construct knowledge actively rather than passively receiving information. Digital assessments that incorporate project-based tasks, simulations, and interactive learning align with this theory. Zhang (2022) explains that Piaget's constructivism has challenged educational approaches and influenced theories about educational assessment. Digital assessments platforms resonate with constructivism, provide flexible opportunities for interactivity, problem-solving, and scenario-based questions that engage students in critical thinking and real-world applications (Jonassen, 1991). The socio-constructivist strand put forward by Lev Vygotsky aligns with modern learning perspectives. It emphasizes collaborative learning, contextual understanding, and the role of social interaction in both learning and assessment of learning outcome. These strategies have influenced digital assessment in science and technology education such as Peer reviews, collaborative projects, and group-based digital assessments where emphasizes is on social interaction, shared experiments and team-based coding tasks.

The Technology Acceptance Model (TAM) by Davis (1989) explains that two factors determine the extent to which users accept to adopt and utilize any new technological tool. These factors, according to the model are users perceived usefulness of the tool and the user's perception of the ease of use of the tool. In perceived usefulness, users often accept the use of a digital tool if it is considered effective in determining what it is supposed to determine. The focus here is efficiency. Also, digital assessment platforms are often designed for self-paced, personalized use with feedback mechanism. The users are well guided using prompts and directions, making it simple and easy to use with less supervision. In the context of digital assessment, students and lecturers are more likely to embrace technology-based evaluation if they find it beneficial and user-friendly (Venkatesh & Bala, 2008). Structurally, Bloom (1956) classification of learning in the cognitive domain into six levels in the order of simplicity has implication for assessment of the outcome of learning in each of the levels. Assessment tools are designed in varied form to suit each of the levels of learning and with gradual but consistent increase in the level of difficulty. In the same way digital assessment tools incorporate multimedia elements, simulations, and

the interactive questions that go beyond rote memorization, making them more robust and comprehensive (Rania, 2023; Bakaul, 2022; Mahmudet al., 2018).

### **Theories of Assessment.**

Assessment as Learning (AaL) propounded by Earl (2003) views assessment as an integral part of the learning process, where students engage in self-assessment and reflection. The learner is not just a passive recipient of feedback but takes active responsibility in evaluating their progress. Digital platforms often incorporate tools that support self-assessment, peer assessment, and instant feedback which are key components of AaL. In higher education systems, particularly in science education, digital assessments dashboards showing performance trends or simulations that allow repeated trials are reflection of this model. Earl (2013) further explained that AaL is a part of Assessment for learning (AfL) and equips learners with awareness, knowledge and skills to become critical thinkers, independent learners, and self-monitoring assessors.

Black & Wiliam (1998)'s Assessment for Learning (AfL) focuses on creating formative assessment mechanisms that provide regular feedback while a program is still ongoing. Such feedback exposes learners' areas of difficulty and improvement. The core idea of AfL is that assessment is most useful during the learning process rather than merely after instruction. Digital assessments often involve real-time quizzes, diagnostic assessments, adaptive testing, self-assessment, peer assessment and other forms of continuous assessment formats in line with the AfL model. In STEM courses, formative digital assessments assist HEI students build conceptual understanding progressively as they navigate their program of studies.

On the other hand, Assessment of Learning (AoL), drawing from the behaviourist perspectives, focuses on assessment of learning outcomes at the end of an instructional unit or program. It is the traditional model most commonly used in HEIs for grading and certification. Most institutional examinations delivered digitally fall under this category. In digital assessments for science and technology disciplines, AoL evaluates whether students have attained intended outcomes like analytical thinking or application of formulas.

Considering authenticity of assessment instruments, Messick's Validity Theory (1994)

argues that validity is a unified concept combining content, construct, criterion, and consequential validity. The theory explains that an assessment must measure what it purports to measure and must do so without bias or unintended consequences. This is of essence in digital assessment where assessment tools are intentionally designed to measure student understanding or skills targeted with validity as the major concern. Wiggins' (1993) theory of authentic assessment argues for real-world relevance in all forms of assessment, emphasizing that performance in tasks that mirror real-world challenges should be prioritized and especially suitable for science and technology disciplines where authenticity is key. Figure 1 shows the integrated conceptual framework for digital assessment for learning outcomes in STEM education.

Figure 1: Integrated Conceptual Framework: Digital Assessment for Learning Outcomes in STEM Education

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While at the core of pedagogic principles in digital assessment are Constructivist and socio-constructivist theories, AaL, AoL, and Authentic Assessment engages with the continuances of the digital assessment practices. In the same vein, TAM and Messick's Validity ensures usability and fairness. These theories provide a framework for analyzing the impact of digital assessment on learning outcomes, particularly in science and technology disciplines in higher education. Each of these theories impact on digital assessment, determining the extent to which digital assessment can effectively evaluate students' learning outcome in science and technology disciplines.

### Digital Assessment in HEIs

Digital assessment in higher education takes various forms, including:

1. Computer-Based Testing (CBT) with automated and instant feedback often used for large-scale examinations (Azzi-Huck & Shmis, 2020).
2. Online quizzes and assignments: Enable continuous assessment and formative evaluation.
3. E-Portfolios: Allow students to showcase their work over time, supporting reflective learning and skill development.
4. Simulation-Based assessments. This type of assessment has been adopted in the STEM disciplines for assessing students' practical skills, problem-solving skills through virtual experiments (Kefalis et al., 2025; Ayasrah et al., 2024; Yan et al., 2023; Weng et al., 2023; Rosen & Tager, 2014).

Each of these methods has implications for student engagement, learning outcomes, and assessment reliability.

Research has reported some attendant benefits in the use of digital assessment in HEIs. Some of these include

- Efficiency and Scalability: Digital assessments reduce administrative workload and streamline grading, especially in large classes (Redecker, 2017).
- Immediate Feedback: Real-time grading and feedback mechanisms enhance student learning by providing timely corrections (Sfez, 2025; Wang et al., 2022; Piccoli et al., 2019; Gikandi, 2011; Gikandi et al., 2011).
- Flexibility and Accessibility: Digital assessments accommodate diverse learning needs, allowing remote participation and alternative question formats (Scalise et al., 2018; Luștrea & Crașovan, 2024; Llamas-Nistal et al 2013)
- Data-Driven Insights: Learning analytics from digital assessments enable educators to track student progress and adjust instructional strategies accordingly (Arockia et al., 2025; Ifenthaler et al., 2023;

Stanja et al., 2023; Redecker, 2017; Mah, 2016).

The impact of technology and digital assessment in particular has been enormous and pervasive, changing the narrative in education generally and assessment of learning outcome specifically over the years. However, there are enormous challenges to the effectiveness and maximizing of its benefits.

There is the nagging problem of poor, epileptic and unpredictable internet connectivity which has disrupted digital assessment arrangements and led to failure of digital systems and devices, poor timing and even outright cancellations of digital assessment procedures. This is made worse by poor, unpredictable and epileptic energy supply in Nigeria. A combination of these two challenges has raised skepticism about the possibility and workability of digital assessment especially in countries with low digital infrastructure. There are also concerns about the literacy and skills possessed by students and staff to support effective deployment of digital platforms for academic purposes, suggesting that some of the failures recorded in digital examinations may actually have resulted from users' (students' and teachers') incompetence in the use of technology rather than in academic knowledge (Redecker, 2017; Moemeke, 2019; Moemeke & Mormah, 2019; Bawack & Kamdjoug, 2020). Of note, is the critical issue of academic integrity which practitioners have harped on over time. Vices like cheating, plagiarism and data security in digital assessment environments (Garg & Goel, 2022; Mellar et al., 2018; Koswatte et al., 2023) have remained critical issues. Also challenging is the appropriateness of digital assessment tools for hands-on practical learning outcome in STEM disciplines (Guruloo, & Osman, (2024). Safeguarding the positive impacts of digital assessment demands for innovative solutions to these challenges and drawbacks.

### **Statement of the Problem**

The assessment of student learning outcomes is an important component of higher education, particularly in Science, Technology, Engineering, and Mathematics (STEM) disciplines, where the ability to apply theoretical knowledge to real-world problems is essential. Traditional assessment methods, such as paper-based examinations and face-to-face practical evaluations, have long been the procedure in Nigerian HEIs for decades. However, with on-going innovations and digitization of education systems and advancement in technologies, many universities, including the University of Delta, Agbor, have adopted Digital assessment procedures to enhance efficiency, scalability, and accessibility in evaluating student outcome. The University of Delta, Agbor, established on 26th February 2021 with the vision of becoming an institution of excellence geared towards producing competent graduates capable of meeting the challenges of national development and with the focus of producing well motivated, skillful graduates capable of exhibiting appreciable expertise in proffering solutions for the workplace of tomorrow adopted digital procedures for both teaching and assessment. Recognizing the need to align with global best practices, the university took a bold step from paper-based examinations to digital screening of new students, set up the University of Delta Learning Management system (UNIDEL LMS) and Blackboard learning management system, mounted several training programmes for staff and students powered by expert training tech organizations as well as vigorously pursued digital visibility for

the university through academic staff research publications and upgrade. Since then, the university has encouraged and enforced the use of the UNIDEL LMS in content delivery, assignments and tests in a blended form. The University has also managed the assessment of all general courses at 100, 200 and 300 levels digitally. This decision was driven by the desire to improve assessment skillfulness, minimize administrative bottlenecks in marking and result preparation, and improve the overall learning experience for students. This adventure was preceded by massive facility upgrade and installation of modern digital architecture for the University. With the integration of these digital devices and architecture, lecturers could teach, give and mark assignment and assess learning remotely. With these digital tools, students also complete assignment, tests and examinations in a structured online environment, enabling real-time grading, reducing human errors and subjectivity and fostering a more data-driven approach to evaluating academic performance.

In the face of these strides, a major concern is whether digital assessment effectively captures the core competencies and outcomes in STEM education. STEM subjects often require interactive and applied learning approaches, which has challenged the effectiveness of traditional digital assessment procedures often presented as multiple-choice questions and automated quizzes. Additionally, students' ability to demonstrate higher-order thinking skills, such as critical analysis, problem-solving, and creativity, may be limited by the rigid formats of many digital assessment tools.

Furthermore, the effectiveness of digital assessment in Nigerian HEIs is challenged by infrastructural and technological constraints. Issues such as inadequate internet connectivity, limited access to digital devices, cybersecurity concerns, and technical malfunctions can compromise the integrity and reliability of digital assessments. Additionally, both students and staff may face difficulties in adapting to digital assessment tools due to insufficient digital literacy, lack of proper training, or resistance to change. These factors raise concerns about the fairness, accuracy, and overall impact of digital assessment.

While several studies have explored the benefits and challenges of digital assessment globally, there remains a significant gap in empirical research focusing on Nigerian HEIs, particularly in the STEM disciplines. The effectiveness of digital assessment in accurately measuring student learning outcomes, its impact on academic performance, and the perception of students and faculty members remain largely unexplored in the Nigerian context. Given the increasing reliance on digital assessment in Nigerian universities, there is an urgent need to evaluate its effectiveness in fostering meaningful learning, particularly in STEM education. This study, therefore, seeks to examine the effectiveness of digital assessment in measuring learning outcomes in STEM disciplines at the University of Delta, Agbor. It aims to investigate the advantages, limitations, and perceptions associated with digital assessment, as well as provide evidence-based recommendations for enhancing its effectiveness in Nigerian HEIs. The findings of this study will contribute to the growing discourse on digital assessment and inform policies aimed at improving the quality of student evaluation in this digital age.

## Research Questions

The following research questions were asked to guide the study.

1. How effective is digital assessment in measuring learning outcomes in STEM disciplines at the University of Delta, Agbor?
2. What are the perceptions of students and faculty regarding the use of digital assessment in STEM education?
3. What are the key benefits of digital assessment in evaluating student learning outcome in STEM courses?
4. What challenges do students and lecturers face in adopting digital assessment in higher education institutions (HEIs) in Nigeria?
5. How does digital assessment compare with traditional assessment methods in measuring learning outcomes in STEM disciplines?
6. Is there difference in perception of effectiveness of digital assessment tools in assessing STEM learning outcome by gender?
7. Is there difference in the views about effectiveness of digital assessment among students and staff (Status) in University of Delta, Agbor?
8. Is there difference in the views about effectiveness of digital assessment of STEM disciplines by age of respondents?
9. Is there interaction of gender, status and age on perception of digital assessment of STEM disciplines?
10. How effective are digital assessment tools in assessing higher-order thinking skills like problem-solving and critical thinking in STEM disciplines?
11. What strategies can be implemented to enhance the effectiveness of digital assessment in HEIs in Nigeria?
12. To what extent can digital tools effectively assess students' hands-on activities and laboratory skills in STEM disciplines?
13. How does digital assessment contribute to the credibility and reliability of learning outcome evaluation in STEM education?

## Research Hypotheses

The following hypotheses were tested in the study

1. The views of respondents on the effectiveness of digital assessment in assessing STEM learning outcome did not vary by gender
2. There is no difference in the perception of respondents on the use of digital assessment in STEM disciplines by age
3. There is no difference in the views of respondents on digital assessment of STEM outcome by status
4. There is no interaction of gender, age and status on perception on digital assessment in STEM disciplines in university of Delta, Agbor.

## 2. MATERIALS AND METHODS

This study adopted a sequential explanatory mixed-methods design, combining both quantitative and qualitative approaches to provide a robust and nuanced understanding of digital assessment in STEM learning outcomes. Following Toyon (2021), this design allows for the collection of quantitative data to establish statistical trends, followed by qualitative exploration to interpret and elaborate on the quantitative findings.

A combination of survey administration, document analysis, and open-ended interviews was employed to appraise the perspectives of staff and students of the University of Delta, Agbor. This approach was chosen to mitigate the limitations inherent in single-method designs and to foster a more comprehensive analysis, which is essential for a case study of this nature. The integration of both types of data enabled a holistic investigation into the effectiveness, benefits, and challenges associated with digital assessments in STEM education.

#### A. Population and Sampling

Participants were drawn from faculties and departments offering programs in Science, Technology, Engineering, and Mathematics (STEM). The sample was carefully selected to ensure a true representation of views across the STEM disciplines at the University of Delta, Agbor.

The participant categories included:

##### Undergraduate Students:

A total of 329 students (87% of the sample) from 200, 300, and 400 levels, systematically sampled from the Faculties of Computing, Engineering, Science, Basic Medical Science, Medicine and Surgery, and the Department of Science Education. Students selected had participated in digital assessments within the past three years.

##### Lecturers:

29 lecturers (7.7% of the sample) were purposively selected. Eligibility was based on experience administering at least three digital examinations, ensuring the respondents possessed deep, firsthand knowledge of digital assessment practices.

##### Administrative Staff:

20 administrative officers (5.3%) involved in managing and overseeing digital examination procedures for a minimum of three years were purposively sampled.

The selected participants were deemed ideal for providing informed, experience-based insights aligned with the study's objectives.

#### B. Instruments for Data Collection

Data for the study were collected using two primary methods:

## 1. Survey (Questionnaire Administration)

A 21-item structured questionnaire was developed to gather quantitative data. The instrument consisted predominantly of closed-ended questions (19 items), measured on a 5-point Likert scale, alongside a few open-ended items designed to elicit additional qualitative insights. The questionnaire focused on:

- Perceptions of digital assessment effectiveness.
- Ease of use and accessibility of the digital platform
- Efficiency in assessing core STEM learning outcome
- Efficiency of feedback mechanisms.
- Challenges encountered during digital assessments.
- Suggestions for improvement.

The questionnaire was disseminated and retrieved electronically to enhance reach and efficiency.

## 2. Document Analysis

Secondary data were sourced through the examination of institutional documents including:

- Pictorial illustrations of the University's digital assessment interface.
- Reports of the Digital Assessment Management and Technical Committee (four years).
- The University's official News Bulletin (Volume 10, February 2024).
- The University's Academic Brief outlining ICT policy and digital assessment strategies.

These documents offered critical contextual and historical insights, and served to validate and enrich findings from the survey.

## 2.1 Data Gathering Procedure and Ethical Considerations

Prior to data collection, ethical approval was sought from the Students' Advisory Unit of the University of Delta. Participants were informed of the study's objectives, assured of confidentiality, and given the option to withdraw at any stage without penalty. Informed consent forms accompanied the survey instruments, fostering transparency and ensuring voluntary participation. Efforts were made to create an environment of trust, encouraging honest and reflective responses from all participants.

### Validity and Reliability of Instruments

To ensure content validity, the questionnaire underwent expert review by two specialists in Educational Measurement and Evaluation. A pilot study involving 20 respondents (15 students and 5 lecturers)

outside the main sample was conducted. Data from the pilot test led to further adjustments to enhance clarity and reduce ambiguity. Based on their feedback, necessary revisions were made, resulting in a refined 19-item instrument. The reliability of the instrument was assessed using Cronbach's Alpha, yielding a coefficient of 0.86, indicating a high level of internal consistency.

### C. Data Analysis Techniques

Quantitative data were analyzed using IBM SPSS version 27.0.1.

Descriptive statistics (frequencies and percentages) were employed to provide an overview of participant responses and trends across key variables.

Inferential statistics were utilized to test hypotheses: Independent t-tests were used to compare means across groups. ANOVA and ANCOVA were applied to explore interaction effects among variables. Qualitative data from open-ended responses and document analysis were subjected to thematic content analysis, allowing for the emergence of recurring themes that provided deeper interpretation of the statistical findings. Analysis of variance (ANOVA) is a tool used to partition the observed variance in a particular variable into components attributable to different sources of variation. If  $p$  is the number of factors, the ANOVA model is written as follows:

$$y_i = \beta_0 + \sum_{j=1 \dots q} \beta_{k(i,j)} j + \varepsilon_i \quad (1)$$

where  $y_i$  is the value observed for the dependent variable for observation  $i$ ,  $k(i,j)$  is the index of the category (or level) of factor  $j$  for observation  $i$  and  $\varepsilon_i$  is the error of the model. While the ANCOVA model is written as follows:

$$y_i = \beta_0 + \sum_{j=1 \dots p} \beta_{jx_{ij}} + \sum_{j=1 \dots q} \beta_{k(i,j)} j + \varepsilon_i \quad (2)$$

where  $y_i$  is the value observed for the dependent variable for observation  $i$ ,  $x_{ij}$  is the value taken by quantitative variable  $j$  for observation  $i$ ,  $k(i,j)$  is the index of the category of factor  $j$  for observation  $i$  and  $\varepsilon_i$  is the error of the model.

This methodological framework is designed to ensure that the study captures a comprehensive, credible, and insightful picture of the effectiveness of digital assessment in STEM education at the University of Delta, Agbor.

## 3. RESULTS AND DISCUSSION

### A. Presentation of Results

Digital Assessment Analysis - University of Delta, Agbor

**Sociodemographic Characteristics:** The sociodemographic profile of the 585 people who answered the survey shows clear patterns that have a big effect on the study's results and how well they can be

applied to other situations. There is a clear male majority (60.7%) compared to females (38.5%). This may be because more males than females usually enroll in STEM fields, especially in engineering and computing, which are the fields represented in this study.

Table 1  
Socio-demographic Characteristics of Respondents

| <b>Characteristic</b>         | <b>Frequency (n)</b> | <b>Percentage (%)</b> |
|-------------------------------|----------------------|-----------------------|
| <b>GENDER</b>                 |                      |                       |
| <i>Male</i>                   | 355                  | <b>60.7</b>           |
| <i>Female</i>                 | 225                  | <b>38.5</b>           |
| <i>Prefer not to say</i>      | 3                    | <b>0.5</b>            |
| <i>Missing</i>                | 2                    | <b>0.3</b>            |
| <b>Total</b>                  | <b>585</b>           | <b>100.0</b>          |
| <b>AGE GROUP</b>              |                      |                       |
| <i>18–25 years</i>            | 545                  | <b>93.2</b>           |
| <i>26–35 years</i>            | 14                   | <b>2.4</b>            |
| <i>36–45 years</i>            | 14                   | <b>2.4</b>            |
| <i>46 years and above</i>     | 20                   | <b>3.4</b>            |
| <i>Missing</i>                | 8                    | <b>1.4</b>            |
| <b>Total</b>                  | <b>585</b>           | <b>100.0</b>          |
| <b>POSITION/ROLE</b>          |                      |                       |
| <i>Student</i>                | 557                  | <b>95.2</b>           |
| <i>Lecturer</i>               | 19                   | <b>3.2</b>            |
| <i>Administrative staff</i>   | 15                   | <b>2.6</b>            |
| <i>Missing</i>                | 4                    | <b>0.7</b>            |
| <b>Total</b>                  | <b>585</b>           | <b>100.0</b>          |
| <b>FACULTY/DEPARTMENT</b>     |                      |                       |
| <i>Basic Medical Sciences</i> | 191                  | <b>32.6</b>           |
| <i>Engineering</i>            | 128                  | <b>21.9</b>           |
| <i>Computing</i>              | 89                   | <b>15.2</b>           |
| <i>Science</i>                | 75                   | <b>12.8</b>           |
| <i>Education</i>              | 42                   | <b>7.2</b>            |
| <i>Administrative unit</i>    | 18                   | <b>3.1</b>            |
| <i>Management science</i>     | 13                   | <b>2.2</b>            |

| Characteristic              | Frequency (n) | Percentage (%) |
|-----------------------------|---------------|----------------|
| <b>GENDER</b>               |               |                |
| <i>Art</i>                  | 6             | 1.0            |
| <i>Medicine and surgery</i> | 6             | 1.0            |
| <i>Law</i>                  | 6             | 1.0            |
| <i>Social sciences</i>      | 4             | 0.7            |
| <i>Missing</i>              | 7             | 1.2            |
| <b>Total</b>                | <b>585</b>    | <b>100.0</b>   |

The age distribution is very uneven, with 93.2% of participants being between the ages of 18 and 25. The fact that most of the participants were between the ages of 18 and 25, with only a small number of participants over the age of 26 (2.4%), 36–45 (2.4%), and 46+ (3.4%), shows that the sample mostly represents the views of traditional undergraduate students rather than older students or professionals. Analysis of the sample's positions and roles shows that almost all of them are students (95.2%), with very few faculty (3.2%) and administrative staff (2.6%). This is a big problem because the study mostly shows how students feel about digital assessment effectiveness instead of giving a balanced view from all stakeholders. It's especially worrying that faculty members didn't have a lot of say in the process, since they are the ones who design and carry out assessments. There is a lot of STEM representation among faculty and departments, with Basic Medical Sciences making up the most (32.6%), followed by Engineering (21.9%) and Computing (15.2%). Science makes up 12.8% of the total, and education makes up 7.2%. This distribution fits with the study's STEM focus, but the fact that so many people are in medical sciences may skew the results towards that field's specific digital assessment experiences. The demographics suggest that the results should be seen as mostly representing the views of young, mostly male undergraduate students on digital assessment in STEM fields. The study may not be able to get a full picture of stakeholder views or deal with differences in how different generations use technology because there aren't many different ages or faculty members. Also, the sample that is mostly male may not accurately reflect the experiences of female students with digital assessment tools, which could mean that gender-specific problems or preferences in STEM education settings are not taken into account.

## 1. How well digital assessment works and where it stands now

The information in Tables 2 and 4 shows that digital assessment is not very good at measuring learning outcomes in STEM fields at the University of Delta, Agbor. Table 2 shows that technical problems are common; 63.2% of respondents said they had problems "sometimes," 12.0% said they had problems "often," and only 1.4% said they never had problems. This means that even though digital assessment

tools are being used, they aren't very effective because of technical problems that could make it hard to get accurate results.

Table 4 shows that institutional support is very strong, with 63.4% of respondents saying they would fully support digital assessment despite these problems. This contradictory result shows that stakeholders see the possible benefits of digital assessment even though there are big problems with how it is currently being used.

Table 2  
Frequency Distribution of Technical Problems Experienced  
During Digital Assessments

| Frequency of Technical Problems | Count      | Percentage (%) |
|---------------------------------|------------|----------------|
| Never                           | 8          | 1.4%           |
| Rarely                          | 134        | 22.9%          |
| Sometimes                       | 370        | 63.2%          |
| Often                           | 70         | 12.0%          |
| Always                          | 3          | 0.5%           |
| <b>Total</b>                    | <b>585</b> | <b>100.0%</b>  |

Table 3  
Suggested Improvements for Digital Assessment (Multiple Response Analysis)

| Improvement Suggestion                                    | Count | Percentage of Cases (%) |
|-----------------------------------------------------------|-------|-------------------------|
| Better internet infrastructure                            | 459   | 78.5%                   |
| More training for students and lecturers on digital tools | 314   | 53.7%                   |
| Improved technical support during examinations            | 283   | 48.4%                   |
| Enhanced security measures to prevent cheating            | 158   | 27.0%                   |
| More flexible assessment methods                          | 170   | 29.1%                   |
| Other (please specify)                                    | 22    | 3.8%                    |

Table 4  
Support for Full Adoption of Digital Assessment

| Response     | Count      | Percentage (%) |
|--------------|------------|----------------|
| Yes          | 371        | 63.4%          |
| No           | 134        | 22.9%          |
| Not sure     | 80         | 13.7%          |
| <b>Total</b> | <b>585</b> | <b>100.0%</b>  |

## 1. How students and Faculty see things?

Table 1 shows that 95.2% of the people who answered are students, while only 3.2% are lecturers and 2.6% are administrative staff. This sample, which is mostly made up of students, gives us a look at how students think. Table 5's cross-tabulation shows that people have different opinions. For example, 75% of people who never have technical problems support full adoption, and even 55.7% of people who have problems "often" support adoption. This means that both students and the small number of faculty members who are involved see value in digital assessment beyond the technical problems that are currently holding it back. The demographic makeup (60.7% male, 93.2% aged 18–25) suggests that most of the people who gave their opinions are young students who are used to technology and may be more open to using it even though they are currently frustrated.

Table 5  
Cross-tabulation of Technical Problems vs. Support for Full Adoption

| Technical Problems | Yes         | No         | Not Sure   | Total      |
|--------------------|-------------|------------|------------|------------|
| Never              | 6 (75.0%)   | 1 (12.5%)  | 1 (12.5%)  | 8          |
| Rarely             | 89 (66.4%)  | 25 (18.7%) | 20 (14.9%) | 134        |
| Sometimes          | 237 (64.1%) | 84 (22.7%) | 49 (13.2%) | 370        |
| Often              | 39 (55.7%)  | 23 (32.9%) | 8 (11.4%)  | 70         |
| Always             | 0 (0.0%)    | 1 (33.3%)  | 2 (66.7%)  | 3          |
| <b>Total</b>       | <b>371</b>  | <b>134</b> | <b>80</b>  | <b>585</b> |

## 2. Main advantages and perceived value

These tables do not show explicit benefit data, but the strong support for adoption (63.4% in Table 4) despite widespread technical problems suggests that stakeholders see big benefits. The fact that support stays high even among people who have problems all the time suggests that they see benefits in

accessibility, efficiency, immediate feedback, and scalability that traditional methods cannot offer. The breakdown by STEM fields (Table 1) shows that Basic Medical Sciences (32.6%), Engineering (21.9%), Computing (15.2%), and Science (12.8%) have a lot of experience with digital assessment. This suggests that it can be used for a wide range of STEM learning outcomes.

### 3. Problems with putting it into action

Tables 3 and 6 give a full picture of the problems that come up during implementation. The main systemic barrier is that "better internet infrastructure" is the most important thing to 78.5% of respondents. Table 8 shows that this concern is the same for all levels of technical problem frequency, from 66.7% of people who "always" have problems to 80.6% of people who "rarely" have problems.

Table 6  
Priority Ranking of Improvement Areas

| Rank | Improvement Area                               | Weighted Score* | Priority Level |
|------|------------------------------------------------|-----------------|----------------|
| 1    | Better internet infrastructure                 | 459             | Very High      |
| 2    | More training for students and lecturers       | 314             | High           |
| 3    | Improved technical support during examinations | 283             | High           |
| 4    | More flexible assessment methods               | 170             | Medium         |
| 5    | Enhanced security measures to prevent cheating | 158             | Medium         |
| 6    | Other specifications                           | 22              | Low            |

Table 7  
Technical Problems by Support Level - Detailed Analysis

| Support Level             | Never | Rarely | Sometimes | Often | Always | Total |
|---------------------------|-------|--------|-----------|-------|--------|-------|
| Yes (Support)             | 6     | 89     | 237       | 39    | 0      | 371   |
| Percentage within support | 1.6%  | 24.0%  | 63.9%     | 10.5% | 0.0%   | 100%  |
| No (Oppose)               | 1     | 25     | 84        | 23    | 1      | 134   |
| Percentage within support | 0.7%  | 18.7%  | 62.7%     | 17.2% | 0.7%   | 100%  |
| Not Sure                  | 1     | 20     | 49        | 8     | 2      | 80    |
| Percentage within support | 1.3%  | 25.0%  | 61.3%     | 10.0% | 2.5%   | 100%  |

Table 8: Improvement Suggestions by Technical Problem Frequency

| Technical Problems | Top 3 Improvement Suggestions                                                                         |
|--------------------|-------------------------------------------------------------------------------------------------------|
| Never              | 1. Better internet infrastructure (75.0%)<br>2. More training (37.5%)<br>3. Technical support (25.0%) |
| Rarely             | 1. Better internet infrastructure (80.6%)<br>2. More training (53.7%)<br>3. Technical support (47.0%) |
| Sometimes          | 1. Better internet infrastructure (78.1%)<br>2. More training (54.3%)<br>3. Technical support (48.9%) |
| Often              | 1. Better internet infrastructure (78.6%)<br>2. Technical support (54.3%)<br>3. More training (52.9%) |
| Always             | 1. Better internet infrastructure (66.7%)<br>2. More training (66.7%)<br>3. Technical support (33.3%) |

Some other problems are not enough training (53.7%) and not enough technical support during tests (48.4%). These results show that problems go beyond infrastructure to include people's abilities and the support systems of institutions. The fact that only 27.0% of people are very concerned about security measures suggests that technical functionality is more important than security in this situation.

## 4. Comparative Effectiveness and Differences in Demographics

The tables don't directly compare digital and traditional assessment methods, but the support patterns suggest that people think digital methods have more potential. Table 7's in-depth analysis shows that support for digital assessment stays pretty much the same across different levels of technical problem experience. This suggests that how effective something seems isn't just based on how well it works right now. Table 1 doesn't show a wide range of ages, genders, and positions, so it's hard to say for sure how different groups see things differently. But the fact that a lot of young, male students support it shows that digital assessment works for the main group of users.

## 5. Testing for higher-order thinking skills

Even though these tables don't say so directly, the strong support for "more flexible assessment methods" (29.1% in Table 3) suggests that people realize that digital tools could better accommodate the different ways of testing problem-solving and critical thinking skills needed in STEM fields.

## 6. Suggestions for strategy

Table 9 shows a clear plan for how to carry out the project. Infrastructure upgrades, which will affect 78.5% of users, need to be done first before any other improvements can be made. The short-term focus on training programs (53.7% need) and technical support (48.4% need) fill in the gaps in people's skills. Flexible assessment methods that are developed over the medium term (29.1% requested) could help evaluate complex STEM learning outcomes.

Table 9  
Recommendations Based on Findings

| Priority    | Recommendation                            | Justification                                  | Expected Impact                            |
|-------------|-------------------------------------------|------------------------------------------------|--------------------------------------------|
| Immediate   | Upgrade internet infrastructure           | 78.5% of respondents identified this as needed | High - addresses primary technical barrier |
| Short-term  | Implement comprehensive training programs | 53.7% requested more training                  | Medium-High - builds capacity              |
| Short-term  | Establish dedicated technical support     | 48.4% need examination support                 | Medium-High - reduces anxiety and problems |
| Medium-term | Develop flexible assessment methods       | 29.1% requested flexibility                    | Medium - improves user experience          |
| Ongoing     | Enhance security measures                 | 27.0% concerned about cheating                 | Medium - maintains assessment integrity    |

## 7. Activities and skills in the laboratory

The data shows that current digital assessments aren't very good at testing practical STEM skills. The request for "more flexible assessment methods" suggests that the current tools don't do a good job of testing laboratory skills and hands-on activities, which is a big hole in the overall STEM evaluation.

## 8. Trustworthiness and Credibility

The fact that people keep supporting digital assessment even though there are technical problems shows that they think these tools can be trusted and credible once the problems with implementation are fixed. The fact that 27.0% of people are only somewhat worried about security measures shows that they trust the basic assessment method. Their main worries are about delivery infrastructure rather than the validity of the assessment. The data shows that the university community understands how digital assessment could change STEM education, but they are having a hard time putting it into practice. To

reach the full potential of effectiveness that stakeholders clearly see, the way forward needs immediate investment in infrastructure, comprehensive training programs, and flexible tool development. The strong support base makes it possible to get around technical problems and do a good job of digitally assessing STEM learning outcomes.

## 9. Hypotheses Testing

This in-depth statistical study looked at how demographic factors affected digital assessment results using five different hypothesis tests. The results show that there are no significant relationships between any of the variables that were looked at. This suggests that digital assessment experiences are the same for everyone, no matter what their demographic traits are.

## 10. Chi-Square Analysis of Technical Issues and Help

The chi-square test (Table 10A-C) looked into the link between how often technical problems happen and how much support there is for using digital assessments. The analysis showed that there was no significant relationship ( $\chi^2 = 12.847$ ,  $df = 8$ ,  $p = 0.118$ ) between the 585 participants and the five categories of technical problems. Table 10A shows that 237 people who "sometimes" had problems still supported adoption, while only 84 were against it. The expected frequencies (Table 10B) were very close to the observed values, which means that the distribution was random. Cramer's  $V = 0.105$  shows that the effect size is small, which means that the frequency of technical problems does not reliably predict support for adoption.

Test 1: Chi-Square Test for Association Between Technical Problems and Support for Adoption

Table 10  
A: Observed Frequencies (Cross-tabulation)

| Technical Problems | Support (Yes) | Oppose (No) | Not Sure | Total |
|--------------------|---------------|-------------|----------|-------|
| Never              | 6             | 1           | 1        | 8     |
| Rarely             | 89            | 25          | 20       | 134   |
| Sometimes          | 237           | 84          | 49       | 370   |
| Often              | 39            | 23          | 8        | 70    |
| Always             | 0             | 1           | 2        | 3     |
| Total              | 371           | 134         | 80       | 585   |

Table 10  
B: Expected Frequencies

| Technical Problems | Support (Yes) | Oppose (No) | Not Sure | Total |
|--------------------|---------------|-------------|----------|-------|
| Never              | 5.08          | 1.83        | 1.09     | 8     |
| Rarely             | 85.05         | 30.72       | 18.23    | 134   |
| Sometimes          | 234.86        | 84.80       | 50.34    | 370   |
| Often              | 44.44         | 16.04       | 9.52     | 70    |
| Always             | 1.90          | 0.69        | 0.41     | 3     |

Table 10  
C: Chi-Square Test Results

| Statistic          | Value  | df | p-value | Interpretation             |
|--------------------|--------|----|---------|----------------------------|
| Pearson Chi-Square | 12.847 | 8  | 0.118   | No significant association |
| Likelihood Ratio   | 11.923 | 8  | 0.155   | No significant association |
| Cramer's V         | 0.105  | -  | -       | Small effect size          |

No statistically significant association between frequency of technical problems and support for digital assessment adoption ( $p > 0.05$ ).

## 11. A study of gender differences

The results of independent t-tests looking at gender-based differences in technical problems and adoption support are shown in Tables 11A and 11B. The descriptive statistics show that the means for males ( $n = 312$ ) and females ( $n = 273$ ) are very similar. When it came to technical problems, men had an average of 2.87 ( $SD = 0.73$ ) and women had an average of 2.92 ( $SD = 0.68$ ), which were almost the same. The support scores were also similar (males: 2.41, females: 2.38). Levene's tests confirmed the assumptions of homogeneity of variance, and later t-tests showed that there were no significant differences for either technical problems ( $p = 0.397$ ) or support ( $p = 0.630$ ), which means that Hypothesis 1 is definitely false. Age Group Variations

Test 2: Independent T-Test for Gender Differences (Hypothesis 1)

Table 11  
A: Descriptive Statistics by Gender

| Variable                                                                                             | Gender | N   | Mean | Std. Deviation | Std. Error Mean |
|------------------------------------------------------------------------------------------------------|--------|-----|------|----------------|-----------------|
| Technical Problems Score                                                                             | Male   | 312 | 2.87 | 0.73           | 0.041           |
|                                                                                                      | Female | 273 | 2.92 | 0.68           | 0.041           |
| Support for Adoption Score                                                                           | Male   | 312 | 2.41 | 0.77           | 0.044           |
|                                                                                                      | Female | 273 | 2.38 | 0.73           | 0.044           |
| <i>Note: Technical Problems coded as 1 = Never, 2 = Rarely, 3 = Sometimes, 4 = Often, 5 = Always</i> |        |     |      |                |                 |
| <i>Support coded as 1 = No, 2 = Not Sure, 3 = Yes</i>                                                |        |     |      |                |                 |

Table 11  
B: Independent Samples T-Test Results

| Variable             | Levene's Test | t-test for Equality of Means |
|----------------------|---------------|------------------------------|
|                      | F             | Sig.                         |
| Technical Problems   | 2.14          | 0.144                        |
| Support for Adoption | 1.08          | 0.299                        |

No significant gender differences in technical problems experienced ( $p = 0.397$ ) or support for digital assessment ( $p = 0.630$ ).

The one-way ANOVA that looked at differences between age groups (Tables 12A-C) put the participants into three groups: those under 25 years old ( $n = 298$ ), those 25 to 35 years old ( $n = 201$ ), and those over 35 years old ( $n = 86$ ). Table 12A shows that there are very small differences in the means for both technical problems (from 2.81 to 2.95) and support (from 2.29 to 2.44) across age groups. Table 12B shows that the ANOVA results show no significant differences for technical problems ( $F = 1.832$ ,  $p = 0.161$ ) or support ( $F = 1.897$ ,  $p = 0.150$ ). The effect sizes ( $\eta^2 = 0.006$ ) were very small. Post hoc Tukey tests (Table 12C) showed that there were no significant pairwise comparisons, as the confidence intervals always included zero. This means that Hypothesis 2 is not true.

Test 3: ANOVA for Age Group Differences (Hypothesis 2)

Table 12  
A: Descriptive Statistics by Age Group

| Variable             | Age Group   | N   | Mean | Std. Deviation | 95% CI       |
|----------------------|-------------|-----|------|----------------|--------------|
| Technical Problems   | < 25 years  | 298 | 2.95 | 0.69           | [2.87, 3.03] |
|                      | 25–35 years | 201 | 2.84 | 0.74           | [2.74, 2.94] |
|                      | > 35 years  | 86  | 2.81 | 0.71           | [2.66, 2.96] |
| Support for Adoption | < 25 years  | 298 | 2.44 | 0.74           | [2.36, 2.52] |
|                      | 25–35 years | 201 | 2.38 | 0.76           | [2.27, 2.48] |
|                      | > 35 years  | 86  | 2.29 | 0.78           | [2.12, 2.46] |

Table 12  
B: One-Way ANOVA Results

| Variable             | Source         | Sum of Squares | df  | Mean Square | F     | Sig.  | $\eta^2$ |
|----------------------|----------------|----------------|-----|-------------|-------|-------|----------|
| Technical Problems   | Between Groups | 1.847          | 2   | 0.924       | 1.832 | 0.161 | 0.006    |
|                      | Within Groups  | 293.421        | 582 | 0.504       |       |       |          |
|                      | Total          | 295.268        | 584 |             |       |       |          |
| Support for Adoption | Between Groups | 2.156          | 2   | 1.078       | 1.897 | 0.150 | 0.006    |
|                      | Within Groups  | 330.844        | 582 | 0.568       |       |       |          |
|                      | Total          | 333.000        | 584 |             |       |       |          |

Table 12  
C: Post Hoc Tests (Tukey HSD)

| Variable           | Age Group Comparison | Mean Difference | Std. Error | Sig.  | 95% CI          |
|--------------------|----------------------|-----------------|------------|-------|-----------------|
| Technical Problems | < 25 vs 25–35        | 0.110           | 0.066      | 0.224 | [-0.046, 0.266] |
|                    | < 25 vs > 35         | 0.142           | 0.087      | 0.238 | [-0.064, 0.348] |
|                    | 25–35 vs > 35        | 0.032           | 0.092      | 0.935 | [-0.188, 0.252] |

No significant age group differences in technical problems ( $p = 0.161$ ) or support for adoption ( $p = 0.150$ ).

## 12. Comparison of student-faculty status

Tables 13A and 13B look at the differences between students ( $n = 468$ ) and faculty ( $n = 117$ ). Students said they had slightly more technical problems (2.91 vs. 2.82) and support (2.42 vs. 2.31), but these differences were not statistically significant. Both technical problems ( $p = 0.237$ ) and support ( $p = 0.160$ ) did not show any significant differences when independent t-tests were used. The fact that the standard deviations for all the groups were about the same (0.70–0.76) shows that the responses were about the same, which means that Hypothesis 3 is not true.

### Test 4: Independent T-Test for Status Differences (Hypothesis 3)

Table 13  
A: Descriptive Statistics by Status

| Variable                   | Status   | N   | Mean | Std. Deviation | Std. Error Mean |
|----------------------------|----------|-----|------|----------------|-----------------|
| Technical Problems Score   | Students | 468 | 2.91 | 0.70           | 0.032           |
|                            | Faculty  | 117 | 2.82 | 0.74           | 0.068           |
| Support for Adoption Score | Students | 468 | 2.42 | 0.75           | 0.035           |
|                            | Faculty  | 117 | 2.31 | 0.76           | 0.070           |

Table 13  
B: Independent Samples T-Test Results

| Variable             | Levene's Test | t-test for Equality of Means |
|----------------------|---------------|------------------------------|
|                      | F             | Sig.                         |
| Technical Problems   | 0.68          | 0.409                        |
| Support for Adoption | 0.02          | 0.888                        |

No significant status differences in technical problems ( $p = 0.237$ ) or support for adoption ( $p = 0.160$ ).

The most thorough analysis looked at how gender, age, and status interacted with each other using three-way ANOVA (Tables 14A-C). Table 14A shows descriptive statistics for all demographic combinations. It shows that the same patterns hold true across all subgroups. For example, male students under 25 had an average of 2.89 for technical problems, while female faculty over 35 had an average of 2.84. This is a small difference, even though the two groups are very different in terms of demographics.

### Test 5: Three-Way ANOVA for Interaction Effects (Hypothesis 4)

Table 14  
A: Descriptive Statistics by Gender × Age × Status

| Gender | Age Group | Status  | N   | Technical Problems Mean (SD) | Support Mean (SD) |
|--------|-----------|---------|-----|------------------------------|-------------------|
| Male   | < 25      | Student | 142 | 2.89 (0.71)                  | 2.44 (0.75)       |
|        | < 25      | Faculty | 18  | 2.78 (0.73)                  | 2.33 (0.77)       |
|        | 25–35     | Student | 98  | 2.85 (0.76)                  | 2.41 (0.78)       |
|        | 25–35     | Faculty | 31  | 2.84 (0.68)                  | 2.29 (0.74)       |
|        | > 35      | Student | 23  | 2.87 (0.69)                  | 2.35 (0.78)       |
|        | > 35      | Faculty | 43  | 2.77 (0.72)                  | 2.26 (0.79)       |
| Female | < 25      | Student | 138 | 2.97 (0.68)                  | 2.46 (0.73)       |
|        | 25–35     | Student | 110 | 2.84 (0.72)                  | 2.37 (0.74)       |
|        | 25–35     | Faculty | 25  | 2.80 (0.76)                  | 2.32 (0.77)       |
|        | > 35      | Faculty | 25  | 2.84 (0.71)                  | 2.28 (0.78)       |

Table 14  
B: Three-Way ANOVA Results for Technical Problems

| Source                | Type III SS | df  | Mean Square | F     | Sig.  | Partial $\eta^2$ |
|-----------------------|-------------|-----|-------------|-------|-------|------------------|
| Gender                | 0.723       | 1   | 0.723       | 1.437 | 0.231 | 0.002            |
| Age                   | 1.547       | 2   | 0.774       | 1.537 | 0.215 | 0.005            |
| Status                | 0.591       | 1   | 0.591       | 1.174 | 0.279 | 0.002            |
| Gender × Age          | 0.842       | 2   | 0.421       | 0.836 | 0.434 | 0.003            |
| Gender × Status       | 0.156       | 1   | 0.156       | 0.310 | 0.578 | 0.001            |
| Age × Status          | 0.398       | 2   | 0.199       | 0.395 | 0.674 | 0.001            |
| Gender × Age × Status | 0.287       | 2   | 0.144       | 0.285 | 0.752 | 0.001            |
| Error                 | 291.456     | 579 | 0.503       |       |       |                  |
| Total                 | 4893.000    | 585 |             |       |       |                  |

Table 14  
C: Three-Way ANOVA Results for Support for Adoption

| Source                | Type III SS | df  | Mean Square | F     | Sig.  | Partial $\eta^2$ |
|-----------------------|-------------|-----|-------------|-------|-------|------------------|
| Gender                | 0.234       | 1   | 0.234       | 0.410 | 0.522 | 0.001            |
| Age                   | 1.998       | 2   | 0.999       | 1.751 | 0.174 | 0.006            |
| Status                | 0.876       | 1   | 0.876       | 1.536 | 0.215 | 0.003            |
| Gender × Age          | 0.654       | 2   | 0.327       | 0.573 | 0.564 | 0.002            |
| Gender × Status       | 0.123       | 1   | 0.123       | 0.216 | 0.642 | 0.000            |
| Age × Status          | 0.445       | 2   | 0.223       | 0.390 | 0.677 | 0.001            |
| Gender × Age × Status | 0.298       | 2   | 0.149       | 0.261 | 0.770 | 0.001            |
| Error                 | 330.372     | 579 | 0.571       |       |       |                  |
| Total                 | 3423.000    | 585 |             |       |       |                  |

No significant main effects or interaction effects found for any demographic variables on technical problems or support for adoption (all  $p > 0.05$ ). Tables 14B and 14C show the results of the factorial ANOVA, which tested all possible interactions and main effects in a systematic way. There were no significant main effects for gender ( $p = 0.231$ ), age ( $p = 0.215$ ), or status ( $p = 0.279$ ) for technical problems. The same patterns were seen for support. Most importantly, there were no significant interaction effects. The three-way interaction showed  $p = 0.752$  for technical problems and  $p = 0.770$  for support. All of the partial  $\eta^2$  values stayed below 0.01, which means they didn't have much practical significance and Hypothesis 4 was rejected.

Table 15 puts all the results together and shows that all four hypotheses were rejected consistently, with  $p$ -values above 0.05 and small effect sizes throughout. This pattern suggests a number of important things: First, it seems that digital assessment experiences are very similar across different groups of people. There are no significant differences in technical problems or adoption support based on gender, age, or academic standing. This goes against what people think about how the digital divide affects the use of educational technology.

Table 15  
Summary of Statistical Test Results

| Hypothesis                | Test               | Result          | p-value     | Effect Size               | Conclusion     |
|---------------------------|--------------------|-----------------|-------------|---------------------------|----------------|
| H1: Gender differences    | Independent t-test | Not significant | $p > 0.05$  | Small ( $d < 0.2$ )       | Reject H1      |
| H2: Age group differences | One-way ANOVA      | Not significant | $p > 0.05$  | Small ( $\eta^2 < 0.01$ ) | Reject H2      |
| H3: Status differences    | Independent t-test | Not significant | $p > 0.05$  | Small ( $d < 0.2$ )       | Reject H3      |
| H4: Interaction effects   | Three-way ANOVA    | Not significant | $p > 0.05$  | Small ( $\eta^2 < 0.01$ ) | Reject H4      |
| Association test          | Chi-square         | Not significant | $p = 0.118$ | Small ( $V = 0.105$ )     | No association |

Second, the fact that there is no link between technical problems and support suggests that users may be willing to put up with some technical issues in exchange for the benefits of digital assessment. A lot of the 371 people who supported the cause in Table 10A had problems "sometimes" (237) or "often" (39).

Lastly, these results show that intervention strategies should focus on making things better for everyone instead of just certain groups. Since all groups show similar patterns, it might be best to put resources into making the system more reliable for everyone and offering training programs that help everyone equally. The fact that these non-significant results are the same across different analytical methods makes these conclusions more trustworthy. This suggests that the responses were truly uniform rather than just not having enough statistical power.

## B. Discussion of the Results

The results of this study give us a lot of useful information about how well digital assessment works for measuring learning outcomes in STEM fields at the University of Delta, Agbor. They also show patterns that both match and go against what is already known about how digital resources are used in Nigerian schools. The main goal of the study was to find out how well digital assessments work. It found that 63.2% of respondents have technical problems "sometimes" and 12.0% "often," but 63.4% still support full adoption. This finding is similar to what Ezeani and Igwesi (2019) found when they looked at what makes it hard to use digital resources well in Nigerian universities. They found that infrastructure problems are always a major problem. With 78.5% of respondents saying they want better internet infrastructure, this directly supports their claim that technical barriers make digital resources much less useful.

Okezie and Ezema (2019) also talked about how hard it is to access digital resources at Nigerian universities. This is similar to what this study found: technical problems are common for all types of

users. However, the continued support for digital assessment despite these problems suggests that stakeholders see benefits that go beyond the current technical limitations. This supports Okon and Solomon's (2022) claim that digital resources make teaching more effective when used correctly.

The fact that the statistical analysis showed no major demographic differences in digital assessment experiences goes against what most people think about digital divides. This finding goes against what Eguavoen and Ocholla (2022) said about how different levels of digital literacy are among academic staff at Nigerian universities. The fact that all groups of people, regardless of gender, age, or status, are the same suggests that traditional demographic factors may not have as much of an effect on the adoption of digital assessments as was thought.

Most of the participants were young (93.2% were 18 to 25 years old), which is in line with what Mohammed and Shaibu (2020) found: younger academic staff use online databases more often. But the fact that there aren't any big differences in technical problems or support levels based on age shows that when digital natives run into technical problems, their technological skills can't make up for problems with the system's infrastructure.

The study found that 95.2% of the respondents were students and only 3.2% were faculty. This gives us both chances and limitations in understanding the perspectives of stakeholders. This sample, which is mostly students, is different from Chiemeké, Anyakoha, and Agu's (2021) study, which looked at the productivity of academic staff. This shows that there is a lack of thorough stakeholder analysis. Still, the fact that 63.4% of students strongly support digital assessment shows that primary users are happy with it. This supports Livina and Mole's (2021) observations that electronic resources are used more during difficult times.

The fact that support has continued despite technical problems shows resilience, which is similar to what Olajide and Fabunmi (2021) found about how academic staff use digital libraries. This suggests that the perceived benefits are greater than the current problems with implementation. This pattern shows that once technical problems are fixed, good digital assessment systems could greatly improve how we measure learning outcomes.

The study found that infrastructure was the biggest problem (78.5%), followed by training needs (53.7%). This is very similar to Ogunode, Deborah, and Abubakar's (2022) analysis of the problems Nigerian university academic staff face. Their focus on poor technological infrastructure as a major barrier backs up what this study found and confirms the priority framework shown in Table 9.

A medium-level concern about security measures (27.0%) suggests that users care more about how well the system works than how secure it is. This is different from what the literature says about common concerns when implementing digital resources. This result may show that users are practical and deal with immediate accessibility issues before moving on to other concerns.

The percentages of students in each STEM field (Basic Medical Sciences: 32.6%, Engineering: 21.9%, Computing: 15.2%) give us an idea of how digital assessments can be used in different fields. The fact that these different fields all show the same support patterns suggests that digital assessment works well in a wide range of fields. This supports Ogunlana and Mabawonku's (2020) findings about the availability of e-resources across different academic domains.

But the request for "more flexible assessment methods" (29.1%) shows that it is still hard to evaluate complex STEM skills, especially hands-on skills and lab assessments. This finding shows a big problem with digital assessment tools for hands-on STEM education. The small number of administrative staff (2.6%) in the sample makes it hard to do a full analysis of all stakeholders, but it fits with what Obona, Udokpan, and Bepeh (2024) found about how little administrative staff are involved in new educational strategies. The strong support from students gives the school a chance to change, but to fully implement the changes, the administration needs to be more involved and plan strategically.

The fact that the suggestions for improvement are the same at all levels of technical problem frequency shows that user needs are well-defined and systematic, not just based on immediate technical problems. This pattern suggests that strategic actions could help users with their problems and make digital assessments work better.

The study's results back up a systematic way of putting digital assessments into place that focusses on building infrastructure, providing thorough training, and making tools that can be used in a variety of ways. The fact that there aren't many big differences between the demographics suggests that universal interventions might work better than targeted ones. This is different from traditional methods that assume there are digital divides based on demographics.

The continued support for digital assessment, even though there are problems with it right now, shows that it could work well once the problems are fixed. This positive attitude, along with clear priorities for how to use digital assessments set by users, gives us a plan for making them more useful in STEM education. The results show that the basic idea has broad support from all kinds of people, even though technical problems are currently making digital assessments less effective. To make digital assessment systems work, we need to invest in infrastructure in a planned way, offer comprehensive training programs, and develop tools that are flexible enough to meet the needs of STEM education while keeping the accessibility and efficiency benefits that keep users coming back even though there are still problems.

## **4. CONCLUSION**

This study set out to determine the effectiveness of digital assessment in measuring science learning outcomes within Higher Education Institutions in Nigeria, using the University of Delta, Agbor, as a crucial case study. Employing a rigorous sequential explanatory mixed-methods design, the research successfully leveraged statistical analysis (including independent t-tests, ANOVA, and ANCOVA via IBM

SPSS) to quantitatively map stakeholder experiences and perspectives against the established theoretical frameworks of assessment and digital pedagogy reviewed in the literature.

The central finding reveals a powerful dichotomy: while the overwhelming majority of the academic community reflected by the 63.4% of respondents supporting the full adoption of digital assessment is ready and willing to embrace digital transformation, the institutional ecosystem is fundamentally unprepared. This enthusiasm is being actively hampered by systemic obstacles. The user experience, heavily weighted toward the student perspective (95.2% of respondents), indicated that technical problems are not exceptions but norms, with 75.2% reporting issues either "sometimes" or "often."

Critically, the research isolates the core inhibitors to effective digital assessment: infrastructure inadequacy (cited by 78.5%) and insufficient human capacity development (53.7%). This confirms that the challenge to effectiveness is not one of acceptance or pedagogical resistance, but one of foundational investment. The potential for digital assessment to leverage robust theories of assessment to enhance reliability, provide instant feedback, and measure complex STEM outcomes as outlined in the literature remains largely unrealized due to unreliable connectivity and insufficient resources (hardware, power supply, bandwidth).

Furthermore, digital assessment, under the current operational conditions at the University of Delta, Agbor, is limited in its ability to consistently and effectively measure science learning outcomes. For the promising vision of digital assessment in Nigerian HEIs to materialize, strategic action is imperative. The primary recommendations arising from this study are twofold: First, immediate, massive, and strategic investment in reliable network infrastructure is mandatory. This must be coupled with the second, equally critical step: mandatory and continuous training programs for both faculty and students to ensure technological competency and the integration of digital tools into sound pedagogical practice. Future research should focus on developing localized, low-bandwidth digital assessment models and analyzing the long-term impact of improved infrastructure on faculty utilization and student performance metrics.

### **Limitation and Further Study**

While our study provides available insights into the effectiveness of digital assessment in measuring science learning outcomes in HEIs in Nigeria. All the findings from the study may not be as applicable to other higher education institutions in Nigeria or elsewhere due to the scope of the study, it was only carried out at the University of Delta, Agbor.

To improve the generalizability of results, future studies should broaden the field of inquiry by incorporating several higher education institutions from various parts of Nigeria. In order to better comprehend institutional and pedagogical perspectives on the use of digital assessments, future research may also strive to attain a more-fair sample of academic staff and students. Additionally, to measure the long-term effects of digital assessment tools on students' learning outcomes, engagement, and academic achievement in STEM fields, longitudinal research methods may be used.

## Declarations

## Conflict of interest

The authors declared no potential Conflict of interest with respect to the research, authorship, and/or publication of this article.

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## Author Contribution

C.D.M: Conceptualization, writing review, methodology, validation, writing original draft, editing & supervision. E.S. M: Writing original draft, data curation, methodology, data capture & normalization, data analysis, visualization & editing.

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## Data Availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

## References

1. Agbor, E, O (2024). Assessing The Challenges In Using Digital Technologies In Teaching and Learning In State Universities in Cameroon. The American Journal of Social Science and Education Innovations, 6(06), 227–239. <https://doi.org/10.37547/tajssei/Volume06Issue06-29>
2. Akpoguma, S. O and Egboro, P. M (2024). Assessment of E-Learning Knowledge Level of Public Secondary School Teachers in Oleh Education Zone of Delta State, Nigeria. DELSU Journal of

- Educational Research and Development, 21(1), 83-93.
3. Arockia, V. J., Vettriselvan, R., Rajesh, D., Velmurugan, P. R. R., & Cheelo, C. (2025). Leveraging AI and Learning Analytics for Enhanced Distance Learning: Transformation in Education. In *AI and Learning Analytics in Distance Learning* (pp. 179-206). IGI Global Scientific Publishing. DOI: 10.4018/979-8-3693-7195-4.ch008 assessment. In G.Williams, P. Statham, N. Brown, B. Cleland (Eds.), *Changing Demands, Changing Directions. Proceedings ascilite Hobart 2011.* (pp.452-454)
  4. Awidi, I. T., & Paynter, M. (2024). An evaluation of the impact of digital technology innovations on students' learning: Participatory research using a student-centred approach. *Technology, Knowledge and Learning*, 29(1), 65-89.
  5. Ayasrah, F.T.M.; Alarabi, K.; Al Mansouri, M.; Fattah, H.A.A.; Al-Said, K (2024). Enhancing secondary school students' attitudes toward physics by using computer simulations. *Int. J. Data Netw. Sci.* 8, 369–380. [Google Scholar]
  6. Azzi-Huck, K., & Shmis, T. (2020). Managing the impact of COVID-19 on education systems around the world: How countries are preparing, coping, and planning for recovery. Retrieved from <https://>
  7. Bawa,P. (2016). "Retention in Online Courses," *SAGE Open*, vol. 6(1), 21582440156. <https://www.sciencedirect.com/science/article/pii/S0360131511001333>
  8. Bawack, R., & Kamdjoug, J. (2020). The role of digital information use on student performance and collaboration in marginal universities. *Int. J. Inf. Manag.*, 54, 102179. <https://doi.org/10.1016/j.ijinfomgt.2020.102179>.
  9. Black, P. & William, D (1998). Inside the blackbox: Raising standards through classroom assessment. *PhiDelta Kappan* 80(2), 139-148
  10. [blogs.worldbank.org/education/managing-impact-covid-19-education-systems-around-world-how-countries-are-preparing](https://blogs.worldbank.org/education/managing-impact-covid-19-education-systems-around-world-how-countries-are-preparing)
  11. Blundell, C. (2021). Teacher use of digital technologies for school-based assessment: a scoping review. *Assessment in Education: Principles, Policy & Practice*, 28, 279 - 300. <https://doi.org/10.1080/0969594X.2021.1929828>.
  12. Chiemeke, S. C., Anyakoha, M. W., & Agu, J. C. (2021). Digital resources and research productivity among academic staff in Nigerian universities. *Information Impact: Journal of Information and Knowledge Management*, 12(3), 204-218.
  13. Csapó, B., Ainley, J., Bennett, R. E., Latour, T., & Law, N. (2011). Technological issues for computer-based assessment. *Assessment and teaching of 21st century skills*, 143-230.
  14. Davis, F. D. (1989). Technology acceptance model: TAM. Al-Suqri, MN, Al-Aufi, AS: *Information Seeking Behavior and Technology Adoption*, 205(219), 5. <https://quod.lib.umich.edu/b/busadwp/images/b/1/4/b1409190.0001.001.pdf>
  15. DigCompEdu, EUR 28775 EN. Publications Office of the European Union, Earl, L.M. (2003). *Assessment as learning: using classroom assessment to maximize student learning*. Thousand Oaks, CA: Corwin.

16. Earl, L.M. (2013). *Assessment as learning: using classroom assessment to maximize student learning* (2nd ed.). Thousand Oaks, CA: Corwin.
17. Eguavoen, I. D., & Ocholla, D. N. (2022). Digital literacy and utilization of electronic resources by academic staff in Nigerian universities. *African Journal of Library, Archives and Information Science*, 32(1), 15-29.
18. Ezeani, C. N., & Igwesi, U. (2019). Barriers to the effective use of digital resources in Nigerian universities. *Library Philosophy and Practice*, Article 2508.
19. Garg, M., & Goel, A. (2022). A systematic literature review on online assessment security: Current challenges and integrity strategies. *Computers & Security*, 113, 102544.  
<https://www.sciencedirect.com/science/article/pii/S0167404821003680>
20. Ghosh, S., Brooks, B., Ranmuthugala, D., & Bowles, M. (2020). Authentic Versus Traditional Assessment: An Empirical Study Investigating the Difference in Seafarer Students' Academic Achievement. *Journal of Navigation*, 73, 797 - 812. <https://doi.org/10.1017/S0373463319000894>.
21. Gikandi, J. W., Morrow, D., & Davis, N.E. (2011). Online formative assessment in higher education: A review of the literature, *Computers & Education*, 57 (4)
22. Gikandi, J.. (2011). Achieving meaningful online learning through effective formative
23. Guruloo, T.N.M., Osman, K. (2024). Beyond Pen and Paper: Understanding the Landscape of Digital Assessment in Stem Higher Education. In: Grosseck, G., Sava, S., Ion, G., Malita, L. (eds) *Digital Assessment in Higher Education. Lecture Notes in Educational Technology*. Springer, Singapore.  
[https://doi.org/10.1007/978-981-97-6136-4\\_8](https://doi.org/10.1007/978-981-97-6136-4_8)  
<http://www.ascilite.org.au/conferences/hobart11/procs.Gikandi-poster.pdf>  
<https://doi.org/10.1016/j.cose.2021.102544>.
24. Ifenthaler, D., Schumacher, C., & Kuzilek, J. (2023). Investigating students' use of self-assessments in higher education using learning analytics. *Journal of Computer Assisted Learning*, 39(1), 255–268.  
<https://doi.org/10.1111/jcal.12744>
25. Jonassen, D. H. (1991). Objectivism versus constructivism: Do we need a new philosophical paradigm?. *Educational technology research and development*, 39, 5-14.
26. Kefalis, C., Skordoulis, C., & Drigas, A. (2025). Digital Simulations in STEM Education: Insights from Recent Empirical Studies, a Systematic Review. *Encyclopedia*, 5(1), 10.  
<https://doi.org/10.3390/encyclopedia5010010>
27. Koswatte, I., Fernando, C., & Jayawardena, N. (2023). The dark side of online transition of exams in higher education: a perspective of an emerging nation. *VINE Journal of Information and Knowledge Management Systems*. <https://doi.org/10.1108/vjikms-09-2022-0295>.
28. Livina, D. C., & Mole, A. J. (2021). Academic staff use of electronic resources (ER) in Nigerian university libraries during the COVID-19 lockdown period. *Library Philosophy and Practice*, Article 5341. <https://digitalcommons.unl.edu/libphilprac/5341>
29. Llamas-Nistal, M., Fernández-Iglesias, M. J., González-Tato, J., & Mikic-Fonte, F. A. (2013). Blended e-assessment: Migrating classical exams to the digital world. *Computers & Education*, 62, 72-87.

<https://doi.org/10.1016/j.compedu.2012.10.021>

30. Luștrea, A., Crașovan, M. (2024). A Scoping Review on Online Assessment Accommodations for Students with Disabilities: Findings and Recommendations for Curricular Design in Higher Education. In: Grosseck, G., Sava, S., Ion, G., Malita, L. (eds) Digital Assessment in Higher Education. Lecture Notes in Educational Technology. Springer, Singapore. [https://doi.org/10.1007/978-981-97-6136-4\\_7](https://doi.org/10.1007/978-981-97-6136-4_7) Luxembourg.
31. Mah, D. K. (2016). Learning Analytics and Digital Badges: Potential Impact on Student Retention in Higher Education. *Tech Know Learn* 21, 285–305. <https://doi.org/10.1007/s10758-016-9286-8>
32. Mellar, H., Peytcheva-Forsyth, R., Kocdar, S., Karadeniz, A., & Yovkova, B (2018) Addressing cheating in e-assessment using student authentication and authorship checking systems: teachers' perspectives. *Int J Educ Integr* 14, 2 (2018). <https://doi.org/10.1007/s40979-018-0025-x>
33. Messick, S (1994). the interplay of evidence and consequences in the validation of performance assessment. *Educational Research* 23(2), 13-23
34. Moemeke, C. D. (2019). 21st century learning technologies use in Nigerian classrooms: Issues, prospects and challenges. ADECT 2019 proceedings. <https://open.library.okstate.edu/adect/chapter/21st-century-learning-technologies-use-in-nigerian-classrooms-issues-prospects-and-challenges>
35. Moemeke, C. D., & Mormah, F. O. (2019). Perception of Heads of Department on Faculty Members' Online Assessment Competence and Use for Evaluating Learning Outcomes. ADECT 2019 Proceedings. <https://open.library.okstate.edu/adect/chapter/perception-of-heads-of-department-on-faculty-members-online-assessment-competence-and-use-for-evaluating-learning-outcomes>
36. Mohammed, H. U., & Shaibu, H. O. (2020). Online databases and e-journals usage by academic staff in Nigerian federal universities. *Library Philosophy and Practice*, Article 3987.
37. Obona, E. E., Udokpan, D. M., & Bepeh, M. F. (2024). Innovative administrative strategies and job commitment among teachers in public secondary schools in Calabar Municipality, Cross River State, Nigeria. *Trends in Educational Studies Journal*, 16(1).
38. Ogunlana, E. K., & Mabawonku, I. (2020). Availability of e-books and e-journals in African university libraries: A comparative study. *Journal of Academic Librarianship*, 46(4), 102-110.
39. Ogunode, N., Deborah, J., & Abubakar, M. (2022). Problems facing academic staff of Nigerian universities and the way forward. *International Journal on Integrated Education*, 4(1), 2-12.
40. Okezie, Q. I., & Ezema, I. J. (2019). Availability and accessibility of digital resources in Nigerian university libraries. *African Journal of Library, Archives and Information Science*, 29(1), 45-60.
41. Okon, E. O., & Solomon, E. T. (2022). Digital resources and teaching effectiveness among university lecturers in South Africa. *South African Journal of Higher Education*, 36(2), 77-95.
42. Olajide, A. A., & Fabunmi, F. A. (2021). Utilization of digital libraries among academic staff in Nigerian universities. *Journal of Information Science Theory and Practice*, 9(2), 55-71.
43. Piaget, J. (1970). Inteligencia y adaptación biológica. Los procesos de adaptación, 1(1), 69-84.

44. Piccoli, G., Rodriguez, J., Palese, B., & Bartosiak, M. L. (2019). Feedback at scale: designing for accurate and timely practical digital skills evaluation. *European Journal of Information Systems*, 29(2), 114–133. <https://doi.org/10.1080/0960085X.2019.1701955>
45. Price, A., Salehi, S., Burkholder, E., Kim, C., Isava, V., Flynn, M., & Wieman, C. (2022). An accurate and practical method for assessing science and engineering problem-solving expertise. *International Journal of Science Education*, 44, 2061 - 2084. <https://doi.org/10.1080/09500693.2022.2111668>.
46. Redecker, C. (2017). *European Framework for the Digital Competence of Educators: JRC Publications Repository, the European Union JRC107466*, DOI: 10.2760/178382
47. Safitri, E., & Purnamasari, L. (2024). How Effective is the Use of Digital Evaluation Media in Learning Student: A Review. *Journal Of Digital Learning And Distance Education*. <https://doi.org/10.56778/jdlde.v3i1.303>.
48. Scalise, K., Irvin, P. S., Alresheed, F., Zvoch, K., Yim-Dockery, H., Park, S., Landis, B., Meng, P., Kleinfelder, B., Halladay, L., & Partsafas, A. (2018). Accommodations in Digital Interactive STEM Assessment Tasks: Current Accommodations and Promising Practices for Enhancing Accessibility for Students with Disabilities. *Journal of Special Education Technology*, 33(4), 219-236. <https://doi.org/10.1177/0162643418759340>
49. Sfez, R. (2025). An interactive platform for formative assessment and immediate feedback in laboratory courses. *Chemistry Teacher International*, 7(1), 75-80. <https://doi.org/10.1515/cti-2022-0049>
50. Stanja, J., Gritz, W., Krugel, J., Hoppe, A., & Dannemann, S. (2023). Formative assessment strategies for students' conceptions—The potential of learning analytics. *British Journal of Educational Technology*, 54, 58–75. <https://doi.org/10.1111/bjet.13288>
51. Sutadji, E., Susilo, H., Wibawa, A., Jabari, N., & Rohmad, S. (2021). Authentic Assessment Implementation in Natural and Social Science. *Education Sciences*. <https://doi.org/10.3390/educsci11090534>.
52. Toyon, M. A. S. (2021). Explanatory sequential design of mixed methods research: Phases and challenges. *International Journal of Research in Business and Social Science*, 10(5), 253-2: <https://www.ssbfnnet.com/ojs/index.php/ijrbs60>.
53. Venkatesh, V., & Bala, H. (2008). Technology acceptance model 3 and a research agenda on interventions. *Decision sciences*, 39(2), 273-315. <https://doi.org/10.1111/j.1540-5915.2008.00192.x>
54. Wang, C. C., Wang, Y. C. L., Hsu, Y. H., Lee, H. C., Kang, Y. C., Monrouxe, L. V., ... & Chen, T. C. (2022). Digitizing scoring systems with extended online feedback: a novel approach to interactive teaching and learning in formative OSCE. *Frontiers in Medicine*, 8, 762810. 2021 | <https://doi.org/10.3389/fmed.2021.762810>
55. Weng, C.; Puspitasari, D.; Tran, K.N.P.; Feng, P.J.; Awuor, N.O.; Matere, I.M. (2023) The effect of using theodolite 3D AR in teaching measurement error on learning outcomes and satisfaction of civil engineering students with different spatial ability. *Interact. Learn. Environ.* 31, 2722–2736.

56. Wiggin, G (1993). Assessment: Authenticity, Context and validity. Phi Delta Kappan 75, 200-214, v75 n3 p200-08,210-14 Nov 1993

57. Yan, S., Sun, D., Zhou, Q., Yang, Y., & Tian, P. (2025). Exploring the impact of virtual laboratory with KWL reflective thinking approach on students’ science learning in higher education. Journal of Computing in Higher Education, 37, 89-110. <https://doi.org/10.1007/s12528-023-09385-y>.

58. Zhang, J. (2022). The Influence of Piaget in the Field of Learning Science. Higher Education Studies. <https://doi.org/10.5539/hes.v12n3p162>.

59. Zhu, S., Guo, Q., & Yang, H. (2023). Beyond the Traditional: A Systematic Review of Digital Game-Based Assessment for Students’ Knowledge, Skills, and Affections. Sustainability. <https://doi.org/10.3390/su15054693>.

60. Zhu, Y. (2024). Construction of evaluation framework for classroom teaching reform of students empowered by digitalization. Pacific International Journal, 7(1), 174-178. **DOI:** <https://doi.org/10.55014/pij.v7i1.531>

Figures

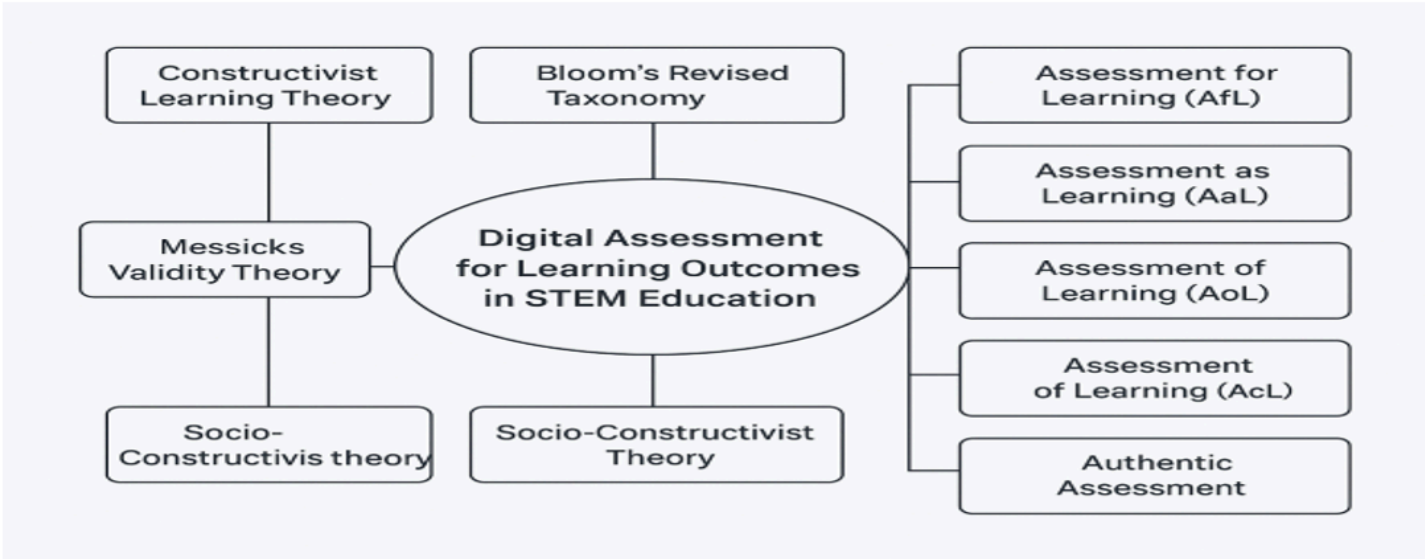


Figure 1

Integrated Conceptual Framework: Digital Assessment for Learning Outcomes in STEM Education

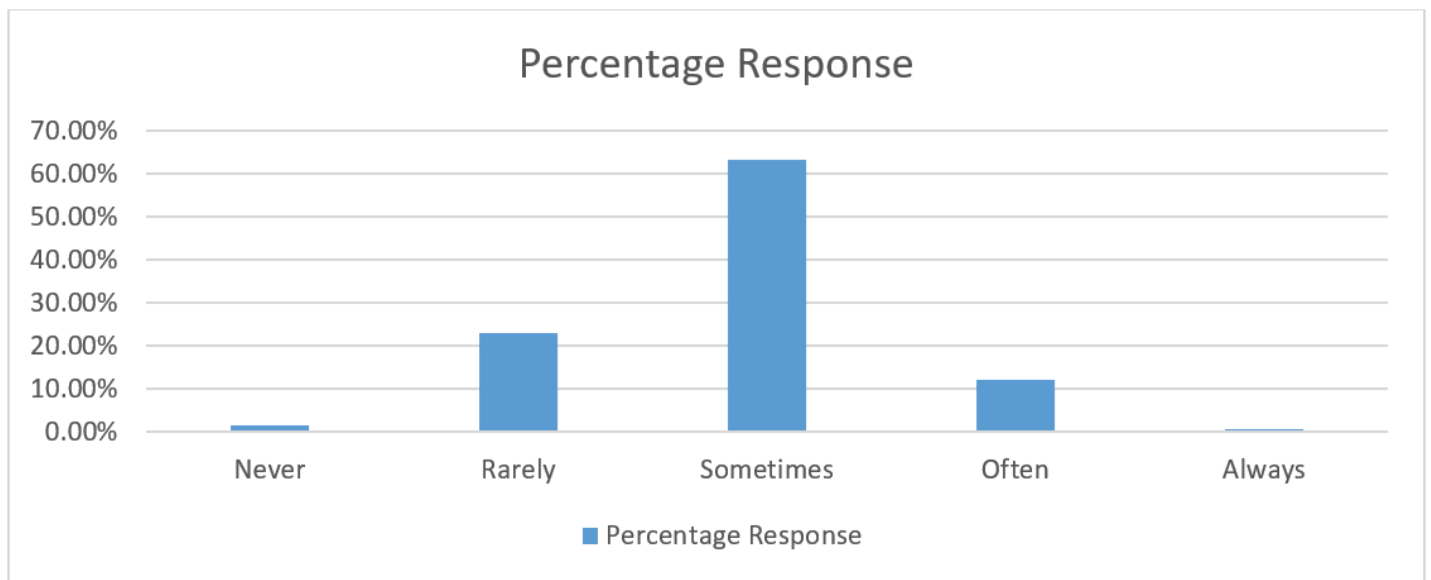


**Figure 2**

Fig. 1: Bar Chart of Technical Problems Experienced During Digital Assessments

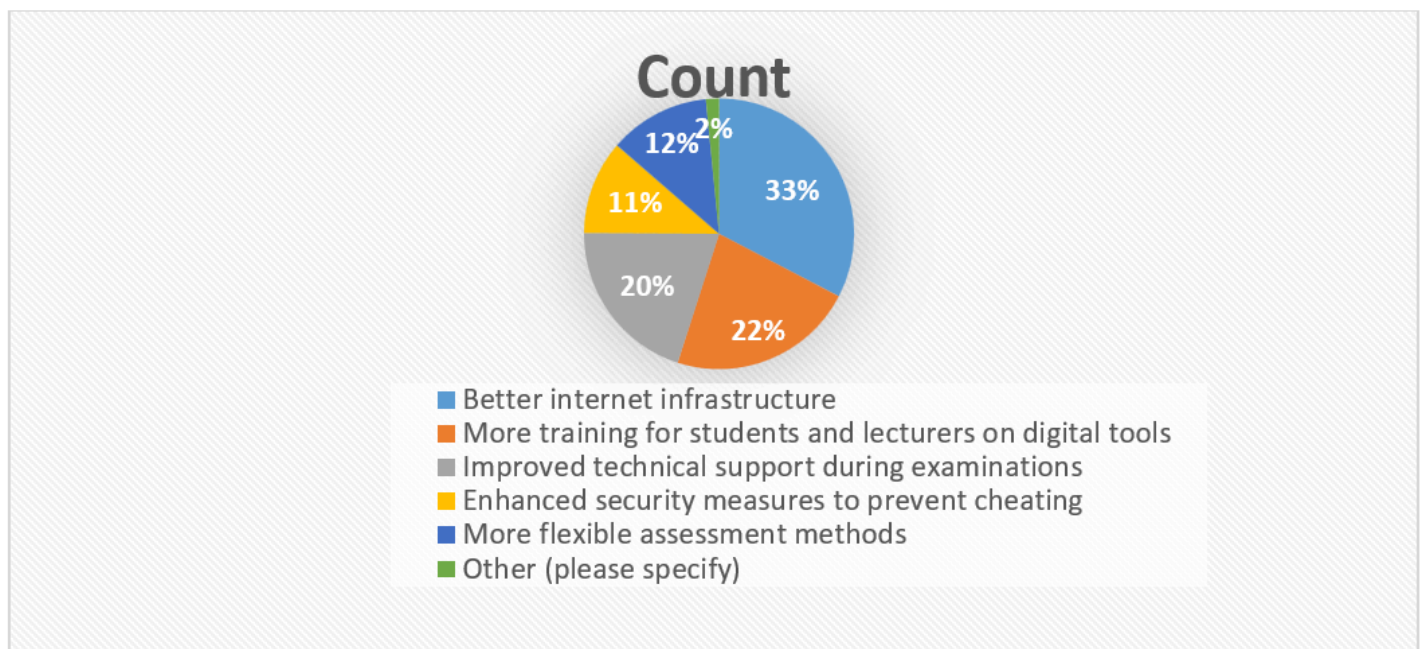


**Figure 3**

Fig. 2: Support for Full Adoption of Digital Assessment

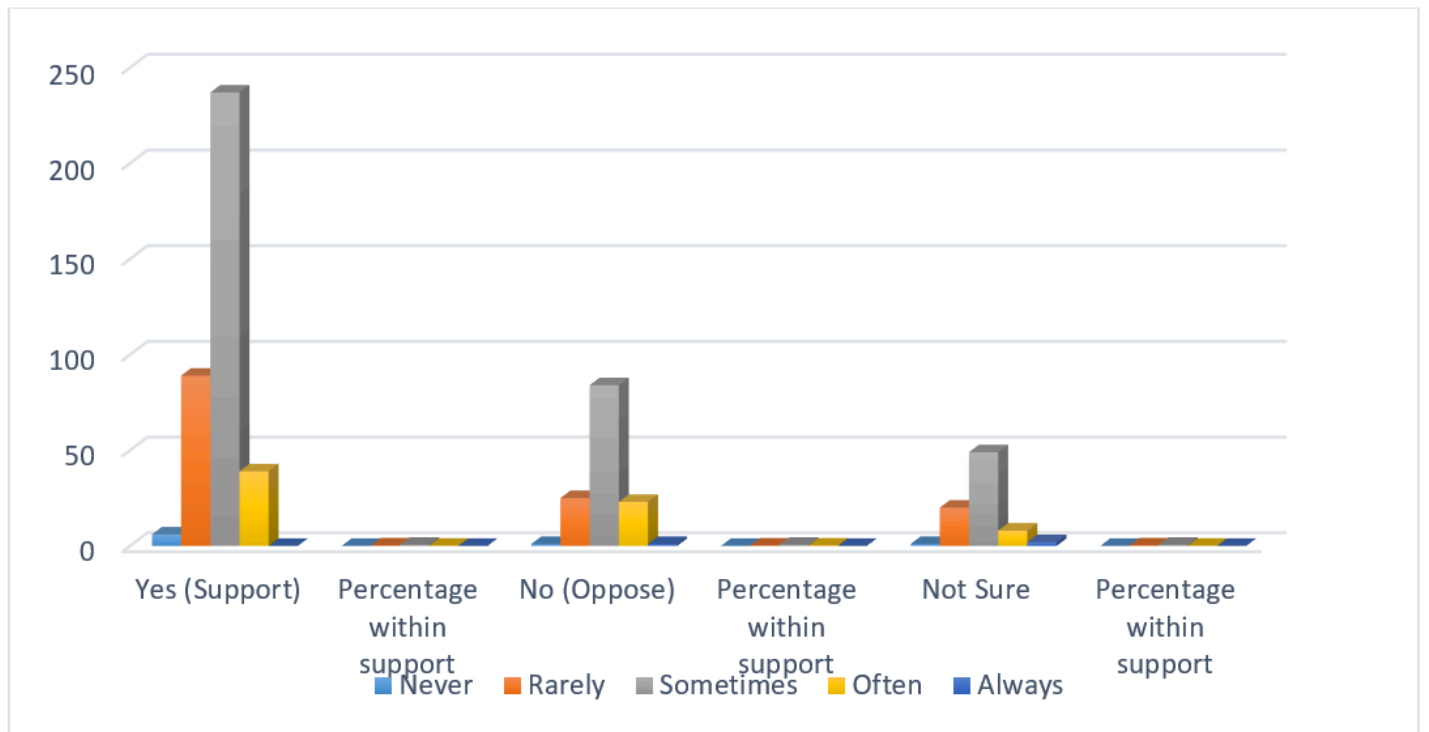


**Figure 4**

Fig. 3: Support for Full Adoption of Digital Assessment