

A National E-assessment Implementation Framework: Assessing Readiness in Secondary Schools and Teacher Education in Tanzania

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ABSTRACT

Nearly every aspect of teaching and learning in the education sector has undergone a technological and pedagogical shift globally. The outburst of the COVID-19 pandemic and the digital advancements in recent years are two major factors that have geared and transformed the sector practically. Due to the rapid population growth and the fee-free education policy, candidate enrollment is constantly expanding, so it is crucial to devise an efficient, cost-effective, and secured approach for conducting educational assessments. This paper explores the possibilities of implementing a national e-assessment system for teacher education and secondary schools in Tanzania. Considering that the e-assessment philosophy is diverse, interdisciplinary, and multidimensional, a holistic research approach focused on library search, document review, and international benchmarking was applied. The e-assessment adoption framework and its design are based on expert opinion. The data used for theoretical and qualitative analysis was captured from the candidate and school registration portals. The study suggests that e-assessment in Tanzania is an inevitable part, especially in the educational system of the 21st century. More importantly, the findings show that e-assessment for teacher education appears to be more pressing as it can be deployed quickly given the computing status and educator readiness in teacher training colleges. For secondary education, e-assessment seems possible in about 6.4% of all schools that currently offer computer science as a subject. To facilitate a seamless adoption process and secure registration of examination centers, a national e-assessment framework is proposed. The framework is tailored to the local context as it applies adaptive staging, on-demand, and ready-to-go approaches to ensure the adopted solution is feasible and

sustainable. Through this framework, you can tell whether certain schools are prepared to switch from conventional pen-and-paper exams to e-assessments.

Keywords: E-assessment, digital learning, teacher education, online examination, secondary school

INTRODUCTION

The use of ICT has revolutionized practically all socioeconomic sectors. While technology is reshaping every aspect of our lives (Redmarker, 2023), e-learning is becoming a common pedagogical and dominant approach in the education sector. The field is undergoing a paradigm shift in aspects related to teaching, learning, and assessment processes (Doğan et al., 2020). This is supported by the increased number of virtual classes where learners and educators interact through e-learning (Chun, Kern, and Smith, 2016) using smart gadgets such as iPads, tablets, laptop computers, and cellphones. Due to its convenience, accessibility, and flexibility in time and space (Nambiar, 2020) and the fact that e-learning is both the present and the future (Ivanova, 2021), its role in the educational sphere remains undeniable. Globally, e-learning is growing at an exponential rate (Yelenevych, 2022), with major impacts expected between 2025 and 2030. However, the applicability of e-assessment remains uncertain, despite the fact that the global outbreak of the COVID-19 pandemic has given momentum to e-learning efforts since 2020.

As an international concern, educational continuity was seriously interrupted by the pandemic (Selvaraj et al., 2021), with over 1.07 billion students affected (Mukhtar et al., 2020). The global landscape of education has changed (Abduh, 2021), bringing with it the new phenomenon of learning from home (Rahardjo & Pertiwi, 2020), where the traditional brick-and-mortar schools were forced to transform into mandatory full-time virtual schools (Van Lancker & Parolin, 2020). Although ICT use cannot replace teachers (Turnage & Goodboy, 2016), the post-pandemic era saw a full realization of e-learning (Yan et al., 2021; Vergonia & Mombas, 2022) with a plethora of digital learning resources at different levels. While the face-to-face classroom remains

the most popular teaching approach, the lessons learned from the pandemic indicate that digital learning processes can be optimized to facilitate the shift towards online education, which will pave the way for the implementation of e-assessment systems. Since online learning varies greatly between schools and academic years (Yan et al., 2021), e-assessment systems can be deployed gradually for a seamless experience. The deployment of e-assessment is notably linked to several technological, pedagogical, financial, and operational issues, rendering its implementation and practicality in real-world scenarios a challenging and complex matter. Some of the major challenges in the electronification of assessment processes include high initial cost of investment (Ghouali et al., 2020), Internet quota, access, and poor signal coverage (Agung et al., 2020; Basuony et al., 2020), and computing infrastructure constraints (Niemi & Kousa, 2020; Wahab & Iskandar, 2020; Bączek et al., 2021). Other challenges include software issues (Abduh, 2021), cheating and security threats on academic integrity (Mukhtar et al., 2020), content design (Doğan et al., 2020), teachers' lack of trust (Mostafa, 2023), unpreparedness and educator readiness (Efriana, 2021; Vergonia & Mombas, 2022), and students' digital illiteracy (Windram et al., 2022). The combination of all these issues signifies that going for online assessment is a process that requires careful planning, preparation, and execution to ensure a smooth adoption.

Adoption of e-assessment is probably an intelligent decision as it helps schools minimize disruption to teaching and learning processes as well as cut down on a vast amount of time, energy, and financial resources wasted in managing an array of examination-related activities. With continued digital advancement and a large userbase of enrolled students in secondary and teacher education, e-assessment remains a strategic choice for the seamless administration of national examinations. While e-assessment appears like a futuristic idea (Redmarker, 2023), it is of the utmost importance to determine whether we are ready for its implementation, given the current computing state. Thus, this paper presents e-assessment readiness for teacher education and secondary schools. The e-assessment adoption framework that

ensures the quality, security, and confidentiality of examination processes is also proposed. The framework is confined to e-assessments carried out in a physically controlled environment.

Review of e-Assessment Systems

Assessment Process

Assessment is a broad procedure that covers a wide range of activities (Ghouali et al., 2020), aiming at assessing the learner's competence and understanding of the learning outcomes. Being the umbrella that lies at the heart of the teaching process (Abduh, 2021; Margiene & Ramanauskaite, 2022), it is critical that both teachers and students understand the assessment cycle (Astin & Antonio, 2012) as depicted in Figure 1.

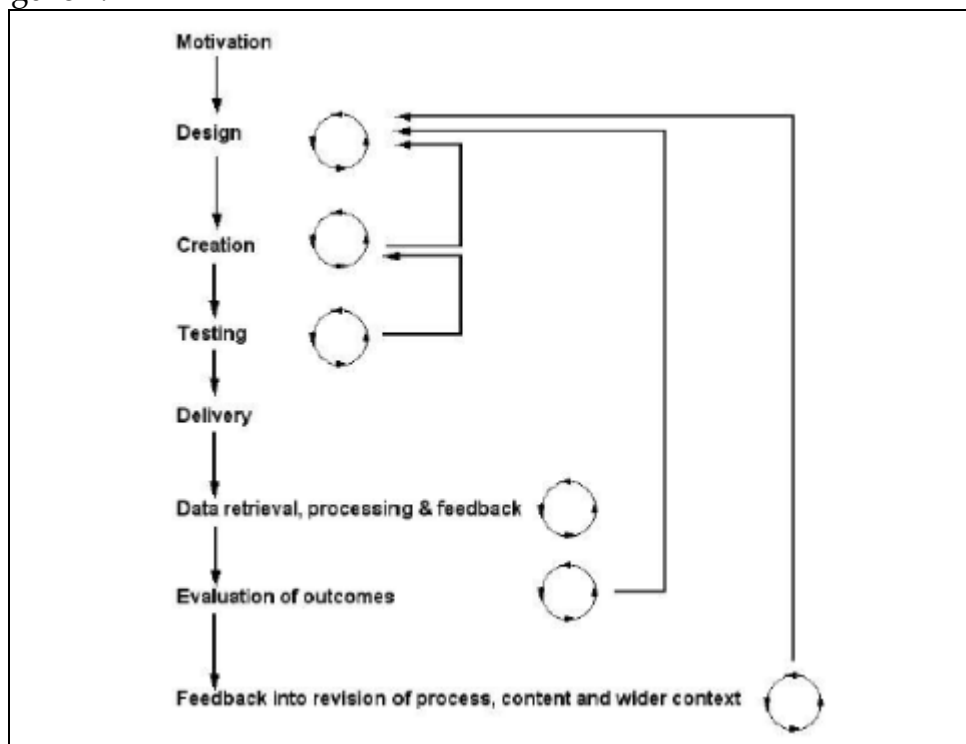


Figure 1. Assessment Cycle

Source: Yan et al. (2021)

Regardless of the differences between formative and summative (Woolfolk et al., 2007), the assessment cycle follows the same

procedure for the *pre-actual-post-exam* activities, including question bank creation, candidates' registration, invigilation, result processing, and award. To get the most out of the assessment process, regardless of whether the assessment is done via ICT or a traditional pen and paper technique, observing pedagogy is essential (Hartell & Strimel, 2019).

e-Assessment Concept

Basically, e-assessment is conducted remotely through the Internet. The e-assessment software automates all examination-related tasks, and it is pedagogically designed (Ashton et al., 2004) to evaluate all learning competencies, including knowledge, comprehension, application, analysis, synthesis, and evaluation. One good example of e-assessment software is the Quiz Module of Moodle LMS (Ally, 2022), a famous e-learning platform (Margiene & Ramanauskaite, 2022). Although the notion of e-assessment has not yet taken shape in secondary schools (Yates et al., 2020; Niemi & Kousa, 2020), its worldwide adoption level is quite promising (Selvaraj et al., 2021), especially in higher education (Margiene & Ramanauskaite, 2022). However, the adoption is highly noticeable in the post-pandemic era (Vergonia & Mombas, 2022).

Benefits and Challenges of e-Assessment

The use of e-assessments can save precious financial and time resources, improve efficiency, and reduce energy spent on administrative processes (Alruwais et al., 2018; Margiene & Ramanauskaite, 2022). Cost items related to printing, transportation, invigilation, marking, and result processing are less expensive for e-assessment adopters. Additionally, less printing means the procedure is more environmentally friendly. From an administration point of view, being web-based, the solution offers convenience, accessibility, and flexibility benefits. The system reduces the likelihood of cheating as it provides high security assurance at the network, browser, and software levels through embedded artificial intelligence (AI) tools. Other notable benefits that adopters gain include reputation, fast evaluation, and instant feedback. Pedagogically, the system supports a variety of question types, such as multiple-choice questions (MCQ), short answer questions (SAQ), long answer questions (LAQ), matching

items (MIQ), and true/false questions (TFQ). Despite all these benefits that adopters' gain, the adoption of e-assessment is still uncertain as technology is considered a challenging and complex matter in real-world scenarios. The use of e-assessments is associated with technological, pedagogical, financial, and operational issues (Biantoro & Arfianti, 2019). The prominent challenges in the electronification of the assessment process include:

- Lack of trust in teachers (Mostafa, 2023)
- Unpreparedness and educator readiness (Efriana, 2021; Vergonia & Mombas, 2022)
- Student digital literacy (Windram et al., 2022)
- Lack of expertise (Peytcheva-Forsyth & Aleksieva, 2021)
- High initial cost of investment (Ghouali et al., 2020)
- Internet quotas, access, and poor signal coverage (Agung et al., 2020; Basuony et al., 2020)
- Constraints of the computing infrastructure, including frequent power outages (Niemi & Kousa, 2020; Wahab & Iskandar, 2020; Bączek et al., 2021)
- Software issues (Abduh, 2021)
- Cheating and security threats to academic integrity (Mukhtar et al., 2020)
- Content design (Doğan et al., 2020)

All these challenges signify that going online successfully is a process that needs to be carefully planned, prepared, and executed.

Research Methodology

The e-assessment philosophy is diverse and interdisciplinary. A holistic approach was applied because e-assessment studies are multidimensional in nature (Ouma et al., 2013; Rachman, 2015), as learners in teacher education and secondary schools have distinct assessment structures tailored to their needs (Margiene & Ramanauskaite, 2022). For that reason, a combination of document review, library search, and international benchmarking was used to conduct the study, which is confined to e-assessment in a physically controlled room.

Document Review

To align the concept with national development goals, a total of five documents were reviewed. These consist of Tanzania's Development Vision 2025, national ICT and education policies, and a rolling strategic plan for the National Examination Council of Tanzania (NECTA, 2020). For theoretical and qualitative analysis, secondary data regarding the computing status of the examination centre was captured from the registration portal. This involved all teacher training colleges (TTC) and secondary schools. On average, a typical examination centre should consist of local servers to support client computers, cable Internet access, a local network, and a power supply for servers and computers. In each centre, parameters for assessment focused on computing infrastructure, in-house expertise, and digital literacy for all key system actors, including candidates, proctors (operators), administrators (invigilators), and technicians (ICT officers).

Library Search and International Benchmarking

A library search and international benchmarking for e-assessment practices were conducted by referring to thirteen examination councils from countries that have taken the lead and taken the necessary initiatives. The referred countries implementing e-assessment for secondary education include Indonesia (2015), Malaysia (2014), Singapore (2014), the Philippines (2018), Australia (2019), England (2019), New Zealand (2020), Israel (2020), Norway (2020), Finland (2020), Scotland (2020), and Pakistan (2020). The e-assessment for teacher education was benchmarked in Kenya from August 21st to August 26th, 2023. The e-assessment data for each examination council was gathered from respective websites through advanced search techniques. For security aspects, the information recorded in the vulnerability database (NVD, 2023) was matched with the three selected e-assessment terminologies for content analysis. The keywords used for data filtration include "online examination," "online testing," "e-assessment," "e-testing," and "e-examination." The NVD source was found to have a total of 29 software vulnerabilities related to e-assessment between 2005 and 2023, as shown in Table 1:

Table 1: E-assessment Security Vulnerabilities

SN	Keyword	Severity Level			Total
		Critical	High	Moderate	
1	Online examination	2	4	11	17
2	Online testing	2	7	3	12
3	E-assessment	0	0	0	0
4	E-testing	0	0	0	0
5	E-examination	0	0	0	0
	Total	4	11	14	29

Source: NVD (2023)

Findings and Discussion

Predictive Factors for e-Assessment Adoption in Tanzania

There are several predictive factors that encourage the development of e-assessments in Tanzania. Four key factors found in the study include *candidate enrollment, digital advancement, the outburst of the COVID-19 pandemic, alignment with the national, regional, and global agenda, and alignment with national policies, standards, and guidelines.*

- (i) **Candidate Enrollment:** The number of candidates enrolled in basic education has increased significantly in the past few years. As Table 2 illustrates, candidates' enrollment is recorded as a constant and an ever-growing entity in Tanzania for Standard Four National Assessment (SFNA), Primary School-Leaving Examination (PSLE), Form Two National Assessment (FTNA), Certificate of Secondary Education Examination (CSEE), and Advanced Certificate for Secondary Education Examination (ACSEE).

Table 2: Candidates Registration Status 2018-2023

SN	Exam Type	No. of Registered Candidates					
		2018	2019	2020	2021	2022	2023
1	SFNA	1,362,642	1,787,045	1,828,268	1,681,791	1,718,896	1,692,797
2	PSLE	957,904	947,077	1,023,950	1,132,084	1,384,186	1,397,370
3	FTNA	545,077	609,381	646,200	652,611	690,341	759,649
4	CSEE	368,037	432,885	448,220	501,039	534,753	543,417
5	ACSEE	77,155	80,216	74,753	81,143	85,414	96,858
	Total	3,310,815	3,856,604	4,021,391	4,048,668	4,413,590	4,490,091

Source: NECTA (2023)

The total number of candidates for national examinations has increased by 1,179,276 between 2018 and 2023. The main driving factors behind the large enrollment of candidates are population growth, the implementation of a fee-free education policy, and increased public and community awareness on education matters. The trend shows that population growth has been continuously increasing over the last six censuses, and its increment has never fallen below 25%, as depicted in Table 3.

Table 3: Population Growth in Tanzania, 1967-2022

SN	Year	Total	Increment	
			N	%
1	2022	61,741,120	16,812,197	37.4
2	2012	44,928,923	10,485,320	30.4
3	2002	34,443,603	11,909,845	52.9
4	1988	22,533,758	5,021,148	28.7
5	1978	17,512,610	5,199,141	42.2
6	1967	12,313,469		

Source: NBS (2023)

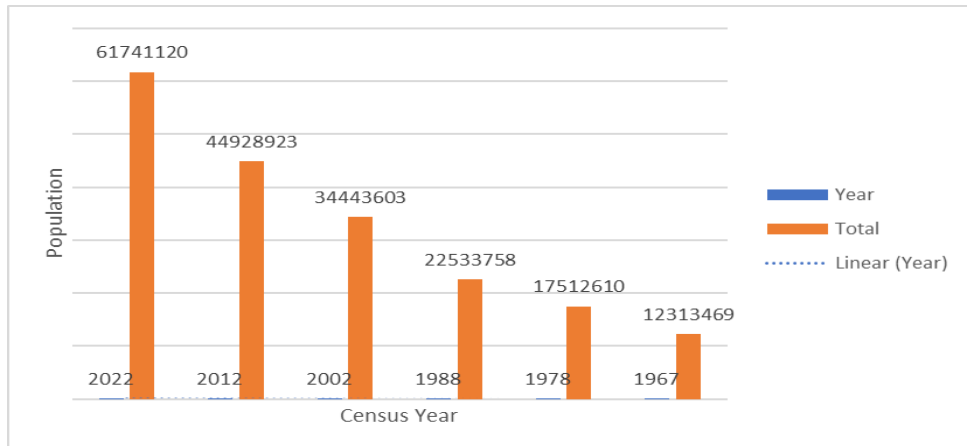


Figure 2: Population Growth in Tanzania

Source: NBS (2023)

As shown in Figure 2, it is predicted that a country's population will reach 100 million by 2042, with an increase of 20 million every ten years. This conforms to the projection by the National Bureau of Statistics (NBS), which estimates a population size of 89,204,781 by 2035 with a growth rate of 2.8% (URT, 2018).

- (ii) **Digital Advancement and Outburst of the COVID-19 Pandemic:** The use of ICT in teaching and learning processes has become a standard practice in the education sector and has proved to be a key factor in e-assessment adoption. Furthermore, the outbreak of the COVID-19 pandemic, which primarily disrupted the continuity of the education system (Selvaraj et al., 2021), has exposed the need for an alternative assessment system (Rahardjo & Pertiwi, 2020). After it has created havoc in a global education system, the lesson learned from the pandemic has principally laid down a future landscape for the adoption and use of e-assessment in Tanzania.
- (iii) **Alignment with the National, Regional and Global Agenda:** Since no country can realistically achieve its national development plans without international cooperation, domestic plans should be aligned with regional and

international agendas. This reveals that integrating ICT into the education sector is in line with the Sustainable Development Goals, the United Nations (UN) Agenda 2030, the Africa Union (AU) Agenda 2063 and the East African Community (EAC) Vision 2050. All these together call for well-educated citizens and skills revolution underpinned by science, technology, and innovation (Ndizera & Muzee, 2018; Carbone, 2018; Walsh et al., 2020; Cilliers, 2021).

(iv) Alignment with National Policies, Standards, and Guidelines:

The use of e-assessments is well aligned with national policies for ICT and education. Furthermore, the idea is well articulated in the TCU Standards and Guidelines for Universities 2019, 3rd Edition, Chapter 7: Blended Learning, which provides e-learning and e-assessment guidelines for higher education (TCU, 2019).

Center Readiness on Computing Infrastructure and Digital Literacy

Critical analysis of center readiness shows that teacher training colleges (TTC) have the necessary facilities to kick-start the e-assessment implementation process. All TTC centers were found to have:

- A well-established computer lab with a server room, reliable Internet access, electricity, and a power backup generator to meet the needs of computing infrastructure.
- Adequate physical space for further expansion.
- Required digital literacy level of both staff and students.
- ICT is taught as a general skill subject. The subject is taught in both GATCE and DSEE curricula in at least 48 colleges.
- Computer science is taught as a teaching subject in eight colleges for the DSEE curriculum and TEHAMA in 57 colleges for the GATCE curriculum.

For secondary education, necessary computing facilities were found in about 380 schools; all 380 schools teach information technology and computer science-related subjects. For Ordinary Level secondary schools, the subject is named *Information and Computer Studies* and is taught in 371 secondary schools. For Advanced Level secondary

schools, the subject is named *Computer Science* and is taught in 14 schools. This data represents 6.4% of the 5,913 secondary schools in Tanzania. Computer science is taught in three subject combinations, which include 7 schools with PMC (Physics, Mathematics, and Computer Science), 6 schools with MCE (Mathematics, Computer Science, and Education), and 1 school with PCE (Physics, Computer Science, and Education).

User Readiness based on Web Experience

User readiness based on web experience was determined through the application of an e-marking system (e-MAS). For the last three years, from 2021 to 2023, the software has been used for the marking of examinations for PSLE and teacher education. The e-MAS platform is regarded as the ideal test for assessing users' readiness since it functions in real-time and concurrent mode, similar to an e-assessment. The fact that all computer science and information technology courses offered in secondary and teacher education have demonstrated a highly promising performance rate, as indicated in Table 4, also justifies user preparedness.

Table 4: Examination Results for IT/CS Subjects 2018-2023

Exam Type	Subject	Pass Rate					
		2018	2019	2020	2021	2022	2023
CSEE	<i>Information & Computer Studies</i>	2,368 (86.11%)	2,393 (85.83%)	2,404 (88.97%)	2,525 (93.69%)	2,805 (91.52%)	-
ACSEE	<i>Computer Science</i>	26 (92.86%)	33 (94.29%)	32 (82.05%)	187 (60.52%)	66 (22.15%)	146 (92.41%)
GATCE	<i>Information & Comm. Tech. (ICT)</i>	349 (97.21%)	628 (98.28%)	773 (98.35%)	774 (98.60%)	826 (97.06%)	1,365 (88.46%)
	TEHAMA	4,851 (99.67%)	4,353 (100%)	3,487 (99.97%)	3,076 (100%)	3,390 (100%)	4,580 (99.98%)
DSEE	<i>Information & Comm. Tech. (ICT)</i>	904 (99.78%)	3,065 (99.84%)	2,718 (99.38%)	2,038 (98.74%)	4,085 (99.68%)	1,699 (99.71%)
	<i>Computer Science</i>	308 (100%)	528 (99.62%)	-	8 (100%)	257 (98.85%)	160 (100%)

Source: NECTA (2023)

Country Readiness

Being a very sensitive web system that requires intensive resources, e-assessment readiness at the country level is crucial to proceeding smoothly and acquiring the desired benefits. As found in this study, the landscape of ICT readiness at the country level was determined using the following indicators:

- (i) **Increase of Internet Users and Mobile Subscribers:** The rapid increase in Internet users and mobile subscribers indicates that the country is doing well in enhancing its digital culture. As of September 2023, the number of Internet users in Tanzania had hit 34,047,407. In the same period, a total of 67,117,449 mobile subscribers were registered. This represents 99.9% of all subscriptions in Tanzania (TCRA, 2023). Table 5 shows the telecom market shares by subscriptions per operator.

Table 5: Operators' Subscriptions Market Shares

Telecom	Jun-Sept 2023			
	Jun	Jul	Aug	Sep
AIRTEL	17,505,139	17,924,973	18,426,704	18,485,232
TIGO	17,484,387	17,505,562	17,756,672	18,181,259
TTCL	1,559,090	1,585,879	1,606,925	1,621,049
SMILE	13,840	13,724	13,404	7,826
HALOTEL	8,410,029	8,332,702	8,436,839	8,266,320
VODACOM	19,116,166	19,732,390	20,165,204	20,555,763
TOTAL	64,088,651	65,095,230	66,405,748	67,117,449

Source: TCRA (2023)

In a period of three months, from June to September 2023, statistics show that the number of telecom subscriptions has increased by over 3 million, representing a quarterly increase of 4.73%. Other (fixed) subscriptions count 83,111 in total, including wired and wireless connections. TCRA (2023) reports that Internet subscribers grew at an average growth rate of 7.8% annually, from 23.8 million in 2018 to 34.5 million in September 2023. The population covered by a mobile broadband network signal for 4G and higher has reached 74%, with

geographical coverage being 55%. The network quality represents average download speeds of 10.81 Mbit/s and 24.29 Mbit/s for mobile and fixed broadband, respectively.

- (ii) **Data Center Investment:** Tanzania has made significant investments in the data center infrastructure for the finance and telecom sectors in both public and private-owned entities. Currently, the National Internet Data Center (NIDC, 2023) and the e-Government Agency Data Center (e-GA, 2023) are the two publicly owned data centers that have been in operation for years. These data centers can provide substantial computing support for the conduct of country-wide e-assessments.
- (iii) **Legal Framework:** Going online necessitates a precise legal and regulatory framework appropriate to the ICT sector. Tanzania's Cybercrimes Act (Magalla, 2018), which was approved in 2015, considers electronic transactions susceptible to criminality. Through this Act, e-content, including e-assessment, has a legal shield from Internet dangers.
- (iv) **Formation of the National TZ-CERT:** Due to its sensitivity, e-assessment requires stringent security for system and data protection at all levels. Currently, the country has a national Computer Emergency Response Team (TZ-CERT), which has been formed within the TCRA structure under Section 124 of the Electronic and Postal Act (EPOCA) Number 3/2010 (TCRA, 2024). At institutional levels, sector-specific CERTs in charge of coordinating the response to cybersecurity incidents were established. This lays the foundation for security threats related to e-assessment systems and ensures a high and effective level of network and information security across the nation.
- (v) **New National ICT Policy (NICTP 2023):** Adoption of e-assessment is well aligned with a newly developed national

ICT policy (2023) that focuses on the ever-evolving landscape of ICT innovation and usage (URT, 2023a). This policy plays a crucial role for the emerging digital economy as well as the national GDP to conform to the Digital Economy Strategic Framework 2023-2033, which aims at transforming Tanzania into a digital-driven economic powerhouse (URT, 2024).

- (vi) **Education and Training Policy of 2014 (Edition of 2023):** Adoption of e-assessment is in line with the national education and training policy (2023 edition), which places special emphasis on enhancing technology-enabled education. The policy is mainly focused on the use of ICT in teaching, learning, and assessment (URT, 2023b).
- (vii) **e-Learning Culture:** Adoption of e-assessment depends heavily on the success and transition to e-learning. In Tanzania, several education stakeholders have launched e-learning projects. In higher education, for instance, the Open University of Tanzania, with over 18 years of e-learning experience, has managed to use asynchronous online content in ATutor LMS in 2004, recorded lectures in Moodle LMS in 2016, and online live sessions through audiovisual conferencing tools in 2021. In basic education, there are several other local initiatives related to e-learning apps, including Shule Direct, SomaApp, Elimu, KLB eLearning, Eneza Education, Ubongo Kids, KiuFunza, Darasa, Classmate, and SmartDarasa. These apps offer a range of learning options, including live online classes, practice tests, video tutorials, and interactive digital textbooks.
- (viii) **e-Assessment Initiative:** The idea of e-assessment is not new in Tanzania. The Open University of Tanzania used Moodle LMS to implement the concept in higher education (Ally, 2022; Ally & Oreku, 2022). In basic education, NECTA created an e-assess prototype to help students self-test their understanding of the learning outcomes through online access. The system

was able to facilitate online item development, item banking, testing, and auto-marking (NECTA, 2018).

The Proposed e-Assessment Adoption Framework

A framework for e-assessment adoption based on ready-to-go, adaptive staging, and on-demand approaches is proposed. The framework is structured with four key enablers, seven prerequisite rules, three management-focused dimensions, four security-focused implementation stages, five adoption levels, and four e-innovation-related aspects. Figure 3 depicts the structural design of the proposed framework.

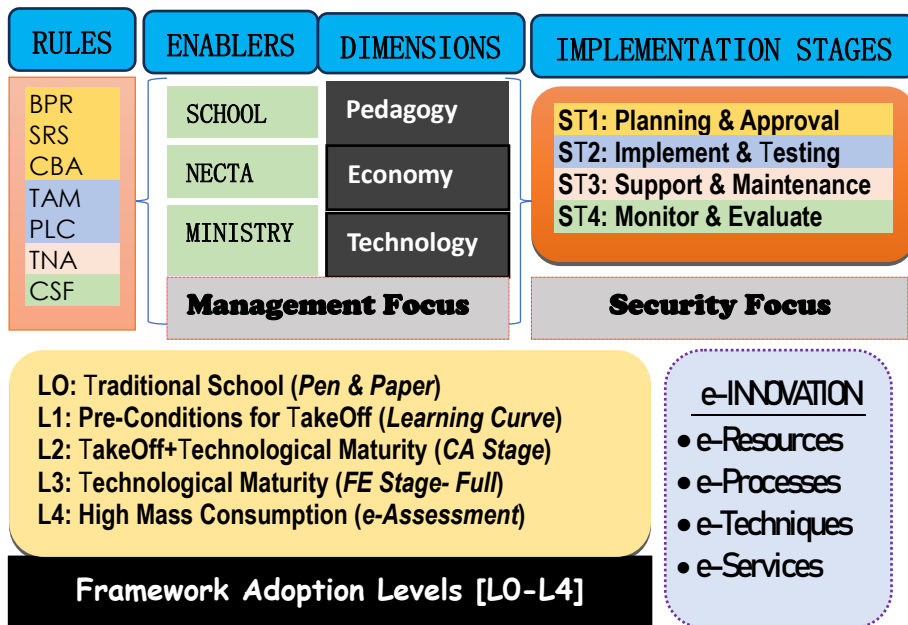


Figure 3: e-Assessment Adoption Framework

The main characteristics of the framework are:

- **On-demand:** the framework offers on-demand services that let the school sign up for the scheme whenever it suits their pedagogical, financial, and technological requirements. This technique conforms to the study by (Zeng et al., 2001; Lindner et al., 2010; Fahland et al., 2011; Küçükaltan, 2020).

- **Ready-to-go:** The framework is based on the ready-to-go approach to enable schools to join the scheme based on their level of readiness, especially in terms of digital literacy and available computing facilities. This study conforms to the study by (Lee et al., 2020; Vergonia & Mombas, 2022).
- **Adaptive Staging:** The framework provides for an adaptive staging approach as it allows for a learn-as-you-go process. This allows the framework to continuously reevaluate and adjust the e-assessment project accordingly based on the existing computing demands, resources, and emerging technologies. This technique conforms well to the study by (Treu, 1985).

The process is guided by the school registration guidelines used by the Ministry responsible for education.

Framework Implementation Stages

For smooth implementation of e-assessment, the framework is designed with four key stages: *planning and approval (st1)*, *implement and testing (st2)*, *support and maintenance (st3)*, and *monitor and evaluate (st4)*. In each stage, the management focus is on the pedagogy, economy, and technology dimensions. Additionally, seven prerequisite rules form the basis for the framework implementation stages. These are the project life cycle (PLC), business process review (BPR), system requirement specification (SRS), cost benefit analysis (CBA), training needs analysis (TNA), critical success factors (CSF), and technology acceptance model (TAM).

St1: Planning and Approval

The procedure for the *planning and approval* stage is regulated by three rules: BPR, SRS, and CBA. The BPR rule helps in the review of pedagogical needs, with major focus areas being continuous assessment, formative and summative assessment, curriculum mapping, a question bank, and lower and higher-order subjective and objective questions. All these are essential for maintaining uniformity, fairness, and quality assessment criteria. The SRS rule places special emphasis on software quality attributes such as accessibility,

compatibility, flexibility, and scalability to accommodate emerging needs. The software is modelled to generate student progress, real-time feedback, auto-marking, auto-grading, ranking reports, a dry run, and a preview of a question paper based on acceptable blueprints and pre-designed templates. Furthermore, the system supports specific requirements such as screen reader compatibility, adjustable font sizes, question formats for science subjects, chemical reactions, mathematical equations, special symbols, graphs, images, statistics, and drawing tools. For the CBA rule, the focus is on an economic feasibility study for the entire e-assessment life cycle. The iceberg model is used to uncover the hidden costs related to software licensing, hardware resources, staffing, electricity, connection, security, usability, and interoperability.

St2: Implement and Testing

In stage 2, the TAM and PLC rules are used. The PLC rule is tailored to *pre-actual* and *post-exam* activities. The pre-exam activities include examiner allocation, planning and budgeting, exam timetable, candidate registration and identification, and question paper generation. The post-exam activities include on-screen marking, APIs for data export, audit records, use of artificial intelligence and machine learning for analysis, certificate layout, and e-certificates. The TAM rule is mainly applicable to user acceptance tests, where ease of use and usability are key aspects to ensure the framework provides a solution with an easy learning curve.

St3: Support and Maintenance

For the *support and maintenance* stage, the PLC and TNA rules apply. The PLC rule is mainly applied to system performance, exam completion rates, system uptime, support network, and technical assistance through a *user-centric help desk* and a *business-centric service desk*. On the other hand, the TNA rule places special emphasis on achieving the necessary digital literacy through training programmes, orientation sessions, pre-exam demos, user manuals, and video tutorials for all main actors involved in the e-assessment process. The framework is focused on recurrent system evaluation, maintenance,

updates, and continuous improvement to optimize system performance for full-scale implementation and long-term success.

St4: Monitor and Evaluate

For *monitor and evaluate stage*, the PLC and CSF rules apply. The focus areas of the PLC rule are integrity policies and academic misconduct, time management, exam-taking strategies, user feedback, emerging needs, system effectiveness, usability and security, and communication strategy. For the CSF rule, the major focus area is the ability to run parallel systems in order to assess usability trends, patterns, learning gaps, and areas for improvement. Some of the set criteria for the CSF rule are:

- The advancements in assessment technology.
- Technology adoption, acquisition, and transition process.
- Effective collaboration with local, regional, and international partners.
- Teamwork, effort level, stakeholder engagement, and benchmarking.
- Budget and cost implications for the hardware, software, and network resources.
- Required expertise with respect to emerging 21st century skills.
- Compliance with the Data Privacy Act and protection regulations
- Data-driven decisions to enhance teaching and learning outcomes.
- Effective communication, transparency, and user trust.

Security Focus

In this framework, security is a focus in all implementation stages, specifically at the question bank, user, software, browsers, network, infrastructure, and invigilation levels from both the server and client sides. The question bank is hosted and protected as on-premises software within the exam domain, where question items and answers are encrypted. The framework enhances auto-authorization through strict access controls and role-based permissions, secure login procedures, and authentication for identity verification using

fingerprints and facial biometric features. At the software level, questions are randomized to alter the order and sequence so that each student is given a different but equivalent exam set. Shuffling is applied to distractors for multiple-choice and numerical questions. The Safe Exam Browser is used as a locker to disable multiple attempts, copy-paste options, keyboard shortcuts, page navigation and switching, browsing activity, backtracking, taking screenshots, time restrictions, instant feedback, and enforcing auto-submit when the allotted time expires. At the network level, the framework emphasizes authentication based on controlled IP addresses, trusted network layers, and the SSL protocol for data encryption between client and server. During the transmission process, stringent security, anti-cheating technology, and confidentiality measures are used for fake feed detection, automated critical security alerts, and notifications on hacking attempts and suspicious activities through warning messages and alerts. Apart from extraneous factors that may lead to the crashing of exam websites, a LAN-based offline exam link is offered as a restore plan in the event of an Internet outage. At the invigilation level, security is enhanced through real-time monitoring and feedback, audio and video streaming, and remote proctoring using AI-powered tools and algorithms. The seating plan is randomized to prevent candidates from synchronous collusion and content sharing, since the framework is confined to a controlled physical classroom.

Roles of Enablers

- **School:** The school is in charge of all infrastructure needs for conducting e-assessments. Among the must-have e-assessment resources at the school level are adequate electricity supply with a power backup facility, a computer lab with a sufficient number of computers, iPads, and tablets, a local server with a LAN connection, and Internet access. Client-side software (operating systems and antivirus programs), auto-surveillance tools for activity logs (web camera, CCTV footage), and biometric attendance registers are also necessary.



Figure 3: e-Exam Room

Source: CC (2023)

- **NECTA:** The responsibility for the server-side services is left to NECTA. The Council oversees the performance of the data center infrastructure in computing, storage, network, and security services based on the registered e-assessment centers, the number of candidates, and the computing workloads. The Council is also in charge of the administration of front- and back-end software, including the design, development, and maintenance of e-assessment software. In the event that a candidate is unable to complete the e-assessment due to issues related to the client or server, the Council will ascertain and determine the cause and make a decision based on the existing examination rules and regulations.
- **Ministry:** The e-assessment philosophy should be adopted when the school is registered in its early stages. The ministry responsible for education is in charge of overseeing all quality attributes required to register a school as a hybrid. The hybrid school should teach and assess via an e-learning platform and must demonstrate teacher-student preparedness, digital literacy, and reliable computing infrastructure. Additionally, the ministry responsible for ICT development will oversee the implementation of the national ICT policy in the education sector as an important step towards e-assessment development.

Adoption Levels

For secure implementation of an e-assessment, the framework presents five adoption levels. These levels are crucial to ensuring a smooth school transition and a gentle adoption process from traditional to online assessment. The adoption levels are:

- Level0→Traditional Schools
- Level1→Pre-conditions for TakeOff (*Preparations*)
- Level2→TakeOff + Technological Maturity Stage (*Continuous Assessment*)
- Level3→Technological Maturity (*Final Examination*)
- Level4→High Mass Consumption

Before using e-assessment, all schools are considered traditional schools at level 0. Schools are registered based on educational delivery between traditional face-to-face and hybrid modes. Since both types have brick-and-mortar classrooms, the shift from conventional pen and paper to hybrid schools follows the same approval procedures used to register Swahili and English-medium schools based on the medium of instruction. In this framework, the adoption of e-assessment is not mandatory; schools join the scheme through on-demand and ready-to-go methods. For level 1, schools aiming to adopt e-assessment must fulfil all the pedagogical pre-conditions as part of preparations for takeoff. The Ministry is in charge of conducting the fieldwork for stage 1 verification to determine readiness for the transition to hybrid mode.

The level 1 pre-conditions that a school must fulfil are the e-learning culture, having computer science as a teaching subject, and reaching an acceptable level of digital literacy. For Level 2, the school must reach technological maturity by having all the necessary facilities required for computing infrastructure together with ICT officers. The salient feature of level 2 is the ability of hybrid schools to conduct school-based e-assessment (SBeA) as well as continuous assessment (CA). 4NECTA determines and approves the field conduct for stage 2 verification. Adoption Level 3 ensures the school is well-equipped with modern and state-of-the-art computing infrastructure. At this level, the

school must have a power backup system, a reliable Internet, and sufficient high-spec computers. Adoption Level 4 is aimed at high mass consumption, in which the school is guided to operate in accordance with *policies, processes, security, infrastructure, skills, and competences* guiding the e-assessment. This is possible through the framework technique of adaptive staging, which allows hybrid schools to practice a *learn-as-you-go* approach throughout all adoption levels.

Discussion

Without a reliable, secure, and seamless e-assessment, examination management is highly challenging. The adoption of e-assessments is considered an intelligent decision and a game-changer in the education industry, where adopters can accrue multiple economic, management, and pedagogical benefits. Considering the current computing status and educator readiness, e-assessment in Tanzania is possible for teacher education. For secondary education, e-assessment is practical in only 6.4% of schools. Pedagogically, e-assessment is a product of e-learning. While e-learning accelerates at an annual growth rate of 16.3% (ExamOnline, 2023), e-assessment implementation is becoming imperative. Since assessment and learning are two sides of the same coin, e-learning ensures that assessment conforms to the teaching and learning methods. The framework also allows for on-demand services (Clero, 2023) where hybrid schools are flexible enough to join the e-assessment scheme. This makes the framework customer-centric and dynamic for integrating and streamlining complex business processes (Zeng et al., 2001). The ready-to-go approach intends to fast-track the adoption process by schools that are fully equipped with e-assessment facilities. The framework is useful for national-level examinations. With a learn-as-you-go technique, the framework provides room to continuously reevaluate the execution process at each decision point to determine the project viability in terms of management, economy, and technology dimensions. At each decision point, the issues of security, cost-effectiveness, and societal acceptance are handled instantly, making it systematic, iterative, flexible, scalable, and structured to accommodate educational levels, a large user base, and emerging functional requirements.

Conclusion and Recommendations

As technology advances and its use in Tanzania becomes evident in teaching and learning, e-assessment initiatives are nowhere to be found. In this study, the e-assessment readiness in teacher education and secondary schools was conducted based on evidence of the current computing infrastructure and digital literacy among key actors. The study reveals that e-assessment is possible in teacher education considering the current computing state. The study also suggests that e-assessment is not possible in all secondary schools, but it can be implemented on demand and stage-wise using a ready-to-go approach. As part of the study, an e-assessment adoption framework is proposed. Since the IT provision varies with the heterogeneity of the schools, the framework ensures a smooth transition process in terms of efficiency, flexibility, and security. The framework is holistic and multidimensional and can be the best reference for countries aiming to adopt e-assessments for national-level examinations. For the country to benefit from using e-assessment, the following are recommended:

- The e-assessment implementation begins with teacher education before secondary school, strategically to instill confidence among key stakeholders.
- The e-assessment comes after e-learning implementation strategically to instill a pedagogical web experience and digital culture.
- The e-assessment implementation involves hybrid schools strategically to instill a sense of maintaining and evaluating the capacity of the computing infrastructure.

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