

A resource-adaptive framework for digital formative assessment in Uganda's competency-based lower secondary schools

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ABSTRACT

Uganda's Competency-Based Curriculum requires assessment practices that generate continuous evidence of learner progress and support timely instructional feedback. In resource-constrained lower secondary schools, however, the transition from examination-oriented assessment to digitally supported formative assessment remains uneven. This study developed and empirically grounded a Resource-Adaptive Digital Formative Assessment (RADFA) Framework for lower secondary schools in the Bukedi Sub-Region of Eastern Uganda. The study was guided by four complementary theoretical perspectives: Formative Assessment Theory, the Technological Pedagogical Content Knowledge (TPACK) Framework, Sociocultural Learning Theory, and Competency-Based Education Theory. Grounded in pragmatism, the study used a sequential exploratory mixed-methods design. Qualitative evidence from interviews, focus group discussions, observations, and document review was integrated with questionnaire data from 743 respondents: 193 teachers, 486 students, 47 head teachers, and 17 policymakers or ICT experts. Descriptive statistics, one-way analysis of variance, Pearson correlation, multiple regression, and thematic analysis were used. Traditional assessment practices remained dominant (overall $M = 3.94$, $SD = 0.83$), whereas competency-based and digital assessment methods were less established (overall $M = 2.90$, $SD = 1.07$); digital assessment recorded the lowest construct mean ($M = 2.47$, $SD = 1.15$). Assessment effectiveness differed significantly by school location, $F(2, 190) = 12.13$, $p < .001$, with rural schools reporting the lowest mean. Availability of digital tools, teacher digital literacy, curriculum requirements, and school leadership support jointly explained 54.6% of the variance in CBC-aligned assessment effectiveness, $R^2 = .546$, $F(4, 188) = 56.58$, $p < .001$. Leadership support was the strongest predictor ($\beta = .523$, $p < .001$), followed by digital-tool availability ($\beta = .343$, $p < .001$) and digital literacy ($\beta = .171$, $p = .002$); curriculum requirements alone were not significant ($\beta = .052$, $p = .391$). The resulting RADFA Framework links resource-adaptive infrastructure, teacher digital pedagogical capacity, digital formative assessment processes, learner agency, and competency development through a continuous feedback loop. Schools should prioritize leadership-led implementation, offline-first technologies, sustainable power, shared-device models, technical support, and assessment-specific teacher development.

Keywords: Competency-Based Curriculum, Digital Formative Assessment, Educational Technology, Resource-Constrained Schools, Teacher TPACK, Uganda

I. INTRODUCTION

Competency-Based Education (CBE) reorients schooling from coverage of prescribed content toward demonstrated mastery of knowledge, skills, values, and practical capabilities. This shift changes the purpose of assessment. Instead of functioning mainly as a terminal judgment, assessment is expected to generate evidence that teachers and learners can use to improve performance while learning is taking place. Formative assessment is therefore central to CBE because it clarifies learning intentions, elicits evidence, provides feedback, and supports instructional adjustment (Açıkgöz & Babadoğan, 2021; Black & Wiliam, 2009). Across African education systems, however, competency-based reform has frequently advanced faster at the level of policy than at the level of everyday classroom assessment (Ogula & Wambiya, 2023; Ruth & Ramadas, 2019).

Uganda introduced the Competency-Based Lower Secondary Curriculum in 2020 to strengthen learner-centred pedagogy, practical application, creativity, communication, collaboration, problem-solving, and other competencies required in contemporary society. The reform expects teachers to collect evidence continuously through projects, performance tasks, portfolios, observation, questioning, peer assessment, self-assessment, and feedback. Yet empirical studies in Uganda report persistent implementation constraints, including large classes, limited materials, uneven teacher preparation, weak assessment guidance, and continued dependence on written examinations (Charles et al., 2023; Chemutai et al., 2024; Kidega et al., 2024; Namubiru et al., 2024). These constraints are especially consequential in rural and semi-rural schools, where teachers must operationalize a demanding assessment model with restricted time, infrastructure, and technical support.

Digital tools can strengthen formative assessment by accelerating feedback, preserving evidence over time, supporting varied response formats, visualizing learner progress, and enabling teachers to identify learning gaps. They can also support digital portfolios, collaborative tasks, self-assessment, competency tracking, and communication with learners; their value depends on educators' capacity to interpret and act on the resulting data (Mandinach & Friedman, 2015). Nevertheless, technology does not produce these benefits automatically. In developing-country contexts, implementation is conditioned by electricity, connectivity, affordability, device access, technical support, teacher competence, institutional leadership, and the fit between a technology and the intended pedagogy (Adie et al., 2023; Çapuk & Kara, 2015). Low-bandwidth and offline systems, including mobile and USSD-SMS applications, demonstrate that useful digital assessment is possible without permanent broadband, but only when design begins with contextual constraints rather than ideal infrastructure assumptions (Muhammad et al., 2023).

The Bukedi Sub-Region of Eastern Uganda offers a critical setting in which to investigate this challenge. Schools in the region vary considerably in location, ownership, electricity reliability, device availability, connectivity, and leadership support. Many serve large classes and share limited ICT facilities among substantial learner populations. In this setting, the relevant question is not simply whether schools possess computers or whether teachers can operate smartphones. The more consequential question is how available technologies, teacher knowledge, institutional support, formative assessment processes, and learner participation can be organized into a sustainable assessment system that advances competency development.

This study addresses that question through an empirical examination of current assessment methods, determinants of digital-tool implementation, teacher technological pedagogical content knowledge (TPACK), learner agency, and competency-oriented outcomes. It then synthesizes the evidence into a Resource-Adaptive Digital Formative Assessment (RADFA) Framework. The framework treats technology as one component of a wider educational ecosystem and explicitly incorporates offline operation, alternative power, local storage, shared access, school leadership, assessment-specific teacher learning, and continuous improvement.

1.1 Statement of the Problem

Uganda's lower secondary curriculum requires continuous, learner-centred, competency-oriented assessment, but implementation in many schools remains dominated by written examinations, class tests, assignments, and teacher-led questioning. These familiar approaches can generate useful evidence, yet they do not consistently provide the longitudinal tracking, rapid feedback, authentic performance evidence, learner reflection, and competency mapping expected under the curriculum. Digital tools could help close this implementation gap, but their use in formative assessment remains fragmented and is often displaced by administrative ICT applications.

Existing research has documented separate barriers to ICT integration and CBC implementation, including inadequate infrastructure, limited teacher preparation, and weak institutional support (Charles et al., 2023; Kidega et al., 2024; Namubiru et al., 2024). Less attention has been given to how these factors operate together in resource-constrained lower secondary schools, how they predict the effectiveness of CBC-aligned assessment, and how empirical evidence can be translated into an implementable digital formative assessment framework. Models developed in well-connected settings commonly presume reliable electricity, adequate devices, permanent internet access, and readily available technical support. Applying such assumptions uncritically in Bukedi risks producing a framework that is conceptually attractive but operationally unusable. A context-sensitive model is therefore needed to connect adaptive infrastructure, teacher digital pedagogical capacity, formative assessment processes, learner agency, and competency outcomes.

1.2 Research Objectives

The main objective was to develop a framework for integrating digital tools into formative assessment within the Competency-Based Lower Secondary Curriculum in the Bukedi Sub-Region. The study specifically sought to:

- (i) Analyze the assessment methods used in lower secondary schools under the Competency-Based Curriculum;
- (ii) Determine the key factors influencing implementation of digital tools in competency-based assessment;
- (iii) Examine digital-tool implementation in formative assessment through relevant theoretical perspectives
- (iv) Develop a context-sensitive framework for resource-adaptive digital formative assessment.

1.3 Research Hypotheses

The quantitative analysis tested the following hypotheses:

- H₀:** Availability of digital tools, teacher digital literacy, curriculum requirements, and school leadership support do not significantly predict the effectiveness of CBC-aligned assessments.
- H₁:** Availability of digital tools, teacher digital literacy, curriculum requirements, and school leadership support significantly predict the effectiveness of CBC-aligned assessments.

II. LITERATURE REVIEW

2.1 Theoretical Framework

The study integrated four complementary theoretical perspectives that collectively explain how digital formative assessment can function effectively in resource-constrained contexts. These theories provided the conceptual lens through which the research problem was examined and the framework was developed.

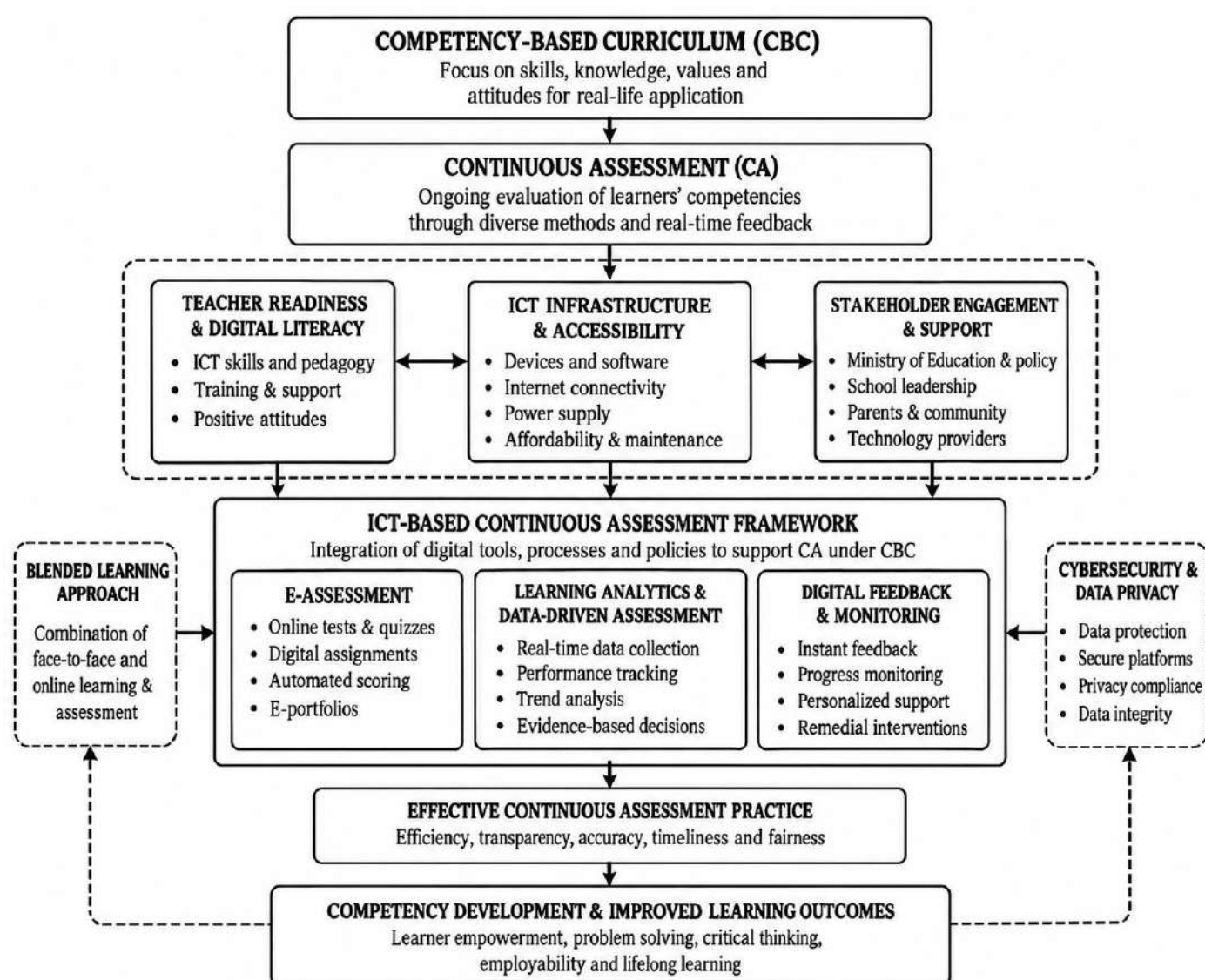


Figure 1

Initial Conceptual Structure for ICT-Enabled Continuous Assessment under the Competency-Based Curriculum

Source: Study conceptual Framework (2026).

2.1.1 Formative Assessment Theory

Formative Assessment Theory, as articulated by Black and Wiliam (2009), provides the foundational understanding of how assessment can support learning. The theory conceptualizes formative assessment as a process in which evidence about learning is elicited, interpreted, and used to decide the next instructional action. This process

encompasses five key strategies: clarifying learning intentions and success criteria, engineering effective classroom discussions and tasks that elicit evidence of learning, providing feedback that moves learning forward, activating students as learning resources for one another through peer assessment, and activating students as owners of their own learning through self-assessment.

The theory directs attention away from technology ownership and toward the quality and use of assessment information. In this framework, the purpose of assessment is to support learning through the active engagement of teachers and learners with evidence of performance. Digital tools are relevant insofar as they enable this purpose; they are not ends in themselves. This perspective informed the study's focus on assessment practices and processes rather than technology adoption alone. The theory also emphasizes that formative assessment is fundamentally context-dependent; the same assessment task may be formative or summative depending on how the evidence is used. This contextual sensitivity aligns well with the resource-adaptive orientation of the present study.

2.1.2 Technological Pedagogical Content Knowledge (TPACK) Framework

The TPACK framework, developed by Mishra and Koehler in 2006 and operationalized by Schmidt et al. (2009), explains the integrated knowledge teachers require to select and use technology meaningfully in educational settings. Technological knowledge alone is insufficient; teachers must connect a tool with appropriate pedagogy, subject content, learner needs, and assessment purposes. Schmidt et al. (2009) operationalized TPACK as interrelated domains of content knowledge, pedagogical knowledge, technological knowledge, and their intersections: pedagogical content knowledge, technological content knowledge, technological pedagogical knowledge, and technological pedagogical content knowledge.

In this study, TPACK provides the mechanism through which resources digital tools, infrastructure, and institutional support are converted into purposeful assessment practices. A teacher with strong TPACK can select a digital tool that fits the assessment purpose, design appropriate tasks, interpret the resulting evidence, and adjust instruction accordingly. A teacher with only technological knowledge may operate devices but lack the pedagogical and assessment expertise to use them productively. This framework was particularly relevant because the study examined not only whether teachers had access to digital tools but also whether they had the integrated knowledge to use those tools for formative assessment purposes.

2.1.3 Sociocultural Learning Theory

Sociocultural learning perspectives, rooted in the work of Vygotsky (1978), emphasize mediation, scaffolding, interaction, and participation in learning processes. Vygotsky's concept of mediation in which tools and signs mediate human activity is particularly relevant to understanding digital technology in education. Digital tools can mediate communication between teachers and learners, enable peer support that extends beyond physical classroom boundaries, extend feedback beyond lesson time, and make progress visible to all participants. They can also create barriers when language, device access, connectivity, or technical failure excludes learners from participation.

The relevant unit of analysis is therefore not the device alone but the interaction among the learner, teacher, peer group, task, and technological artifact. This sociocultural lens informed the study's attention to learner agency, peer assessment, and classroom interaction patterns. It also emphasized that technology implementation must consider the social and cultural context in which it occurs, including language, power dynamics, and participation structures.

2.1.4 Competency-Based Education Theory

Competency-Based Education Theory focuses attention on progressive mastery, authentic performance, application, and observable outcomes (Açıkgöz & Babadoğan, 2021). It establishes competency development not technology adoption and not merely curriculum coverage as the final criterion of success. This perspective ensured that the framework developed in this study remained focused on educational outcomes rather than technological inputs.

Competency-based theory also draws attention to the need for authentic assessment tasks that require learners to apply knowledge and skills in contexts resembling real-world situations, a requirement that has implications for the types of digital tools and assessment designs that are educationally appropriate. The theory emphasizes that learning is defined in relation to explicit outcomes and demonstrated competence rather than time spent receiving instruction. Its effectiveness depends on assessment systems capable of revealing what learners can apply, explain, create, and perform. In African settings, the promise of this orientation includes greater relevance, practical learning, and responsiveness to twenty-first-century demands, but implementation is frequently constrained by inherited examination cultures and limited institutional capacity (Ogula & Wambiya, 2023; Ruth & Ramadas, 2019).

Together, these four perspectives support a pathway in which enabling conditions and teacher capacity shape formative assessment processes; those processes influence learner agency and engagement; and sustained participation supports competency development. The conceptual framework guiding this study (Figure 1) linked competency-based

curriculum requirements, continuous assessment practices, ICT readiness and infrastructure, stakeholder engagement, digital assessment processes, and competency outcomes in a dynamic system.

2.2 Empirical Review

The empirical review is organized around the four research objectives of the study. For each objective, relevant previous studies are critically synthesized, and gaps in the existing literature are identified.

2.2.1 Assessment Methods Used in Competency-Based Lower Secondary Schools

Competency-Based Education reorients schooling from coverage of prescribed content toward demonstrated mastery of knowledge, skills, values, and practical capabilities. This shift changes the purpose of assessment. Instead of functioning mainly as a terminal judgment, assessment is expected to generate evidence that teachers and learners can use to improve performance while learning is taking place (Black & Wiliam, 2009). Formative assessment is therefore central to CBE because it clarifies learning intentions, elicits evidence, provides feedback, and supports instructional adjustment (Açıkgöz & Babadoğan, 2021).

Uganda introduced the Competency-Based Lower Secondary Curriculum in 2020 to strengthen learner-centred pedagogy, practical application, creativity, communication, collaboration, problem-solving, and other competencies required in contemporary society. The reform expects teachers to collect evidence continuously through projects, performance tasks, portfolios, observation, questioning, peer assessment, self-assessment, and feedback. However, empirical studies in Uganda report persistent implementation constraints that affect the adoption of varied assessment methods.

Charles et al. (2023) conducted a systematic literature review identifying factors affecting CBC implementation in Ugandan secondary schools. Their review found that teacher preparation, instructional materials, assessment guidance, and institutional support were consistently identified as barriers to effective implementation. The review also noted that despite curriculum expectations for continuous and varied assessment, teachers continued to depend heavily on written examinations. This finding suggests that the transition from traditional to competency-based assessment methods is not automatic but requires deliberate support and capacity building.

Chemutai et al. (2024) examined teacher perspectives on the status of lower secondary curriculum implementation in Uganda. Their study found that while teachers generally supported the goals of CBC, they encountered practical difficulties in assessment design, resource provision, workload management, and translation of broad competency expectations into observable evidence. The study concluded that teachers needed more guidance and support to implement the assessment expectations of the curriculum effectively.

Kidega et al. (2024) investigated challenges facing teachers in implementing CBC in Gulu City secondary schools. Their research identified teacher training gaps, resource limitations, and institutional support deficiencies as key barriers. The study specifically noted that assessment practices remained heavily weighted toward written examinations despite curriculum expectations for varied evidence collection. This finding is consistent with other studies in the region and suggests that the persistence of examination-oriented assessment is a systemic challenge rather than an isolated issue.

Namubiru et al. (2024) documented teacher perceptions of CBC implementation in Bundibugyo and Ntoroko districts. Their study found that while teachers understood the rationale for competency-based assessment, they struggled with practical implementation due to large class sizes, limited materials, and inadequate training. The study also noted that the pressure of national examinations continued to influence classroom assessment practices, with teachers prioritizing content coverage over competency development.

Nsengimana et al. (2024) provided a broader reflection on science competency-based curriculum implementation in Sub-Saharan African countries. Their review identified common challenges across the region, including limited teacher preparation, inadequate resources, and examination-oriented assessment cultures. The study argued that successful implementation requires not only curriculum reform but also changes in assessment systems, teacher education, and institutional support structures.

Across these studies, a consistent finding emerges: while curriculum reform has introduced expectations for varied, continuous, and competency-oriented assessment, implementation in many schools remains dominated by written examinations, class tests, assignments, and teacher-led questioning. These familiar approaches can generate useful evidence, yet they do not consistently provide the longitudinal tracking, rapid feedback, authentic performance evidence, learner reflection, and competency mapping expected under the curriculum. The gap between policy expectations and classroom practice represents a significant implementation challenge that the present study addresses by examining current assessment methods in the Bukedi Sub-Region.

2.2.2 Factors Influencing Implementation of Digital Tools in Competency-Based Assessment

The integration of digital tools into assessment is shaped by multiple interconnected factors. Understanding these factors is essential for developing strategies that effectively support digital formative assessment in resource-constrained contexts.

Infrastructure and Resource Availability. Research consistently identifies infrastructure as a foundational factor influencing digital tool implementation. Çapuk and Kara (2015) provided a critical discussion of ICT integration within developed and developing world contexts, cautioning against assuming that identical technologies will produce identical outcomes across contexts. Their analysis emphasized that reliable power, connectivity, technical support, institutional routines, and teachers' pedagogical competence mediate implementation in ways that are often invisible in studies conducted in well-resourced settings. The study concluded that technology integration strategies must be context-sensitive and account for the specific infrastructure constraints of developing-country settings.

Adie et al. (2023) examined offline internet for remote learning in low-resource environments, demonstrating the importance of offline and locally accessible resources where permanent connectivity is unavailable. Their research showed that technological solutions need not require permanent broadband connectivity to be educationally useful; offline platforms and locally stored resources can support learning and assessment functions even in the absence of reliable internet access.

Muhammad et al. (2023) conducted a usability evaluation of mobile USSD-SMS interactive result checking systems for resource-constrained settings using the System Usability Score. Their study showed that even simple text-based systems can support assessment functions when designed with contextual constraints in mind. The research demonstrated that low-bandwidth and offline systems can provide useful digital assessment services without permanent broadband, but only when design begins with contextual constraints rather than ideal infrastructure assumptions.

Teacher Digital Literacy and TPACK. Teacher capacity is another critical factor influencing digital tool implementation. Schmidt et al. (2009) developed and validated an assessment instrument for preservice teachers' technological pedagogical content knowledge (TPACK), establishing the framework as a useful lens for understanding the integrated knowledge teachers require for effective technology integration. Their research showed that meaningful integration occurs at the intersection of technology, pedagogy, and content; training that addresses only one domain is insufficient.

Mandinach and Friedman (2015) examined how schools of education can help build educators' capacity to use data. Their research emphasized that the value of digital tools depends on educators' capacity to interpret and act on the resulting data; technology does not produce educational benefits automatically. This finding is particularly relevant to formative assessment, where the quality of teacher interpretation and instructional response determines whether assessment evidence supports learning.

School Leadership and Institutional Support. The role of school leadership in supporting technology integration is well-documented in the literature. Studies of CBC implementation in Uganda consistently identify leadership support as an enabling factor (Charles et al., 2023; Chemutai et al., 2024; Kidega et al., 2024). Leaders determine whether resources are budgeted, maintained, scheduled, monitored, and connected to assessment priorities, and whether teachers receive time, coaching, peer learning, and permission to experiment. Without leadership commitment, resources and support structures are unlikely to be prioritized.

Contextual Factors. Location, ownership, and other contextual characteristics influence digital tool implementation. Studies in Uganda have found that rural schools face additional constraints related to infrastructure, connectivity, and professional support (Charles et al., 2023; Kidega et al., 2024). These contextual factors create a clustered disadvantage that requires differentiated support strategies. The present study addresses this gap by examining location-based differences in assessment effectiveness and identifying the specific constraints faced by rural schools.

While existing research has documented separate barriers to ICT integration and CBC implementation, less attention has been given to how these factors operate together in resource-constrained lower secondary schools, how they predict the effectiveness of CBC-aligned assessment, and how empirical evidence can be translated into an implementable digital formative assessment framework. The present study addresses this gap by examining the joint contribution of digital-tool availability, teacher digital literacy, curriculum requirements, and school leadership support to CBC-aligned assessment effectiveness.

2.2.3 Digital Tool Implementation in Formative Assessment: Theoretical Perspectives

Several theoretical perspectives have been applied to understand digital tool implementation in formative assessment. Each perspective offers different insights and carries different implications for practice in resource-constrained contexts.

Formative Assessment Theory and Digital Tools. From the perspective of Formative Assessment Theory (Black & William, 2009), digital tools can strengthen formative assessment by accelerating feedback, preserving evidence over time, supporting varied response formats, visualizing learner progress, and enabling teachers to identify learning gaps.

Digital tools can also support digital portfolios, collaborative tasks, self-assessment, competency tracking, and communication with learners. However, the theory emphasizes that technology does not produce these benefits automatically; its value depends on the quality of assessment design and the capacity of teachers and learners to use the resulting evidence.

Research applying this perspective in developing-country contexts has found that digital tools can support formative assessment when designed with contextual constraints in mind. Adie et al. (2023) demonstrated that offline platforms can support remote learning and assessment in low-resource environments. Muhammad et al. (2023) showed that USSD-SMS systems can remain usable where smartphones, broadband, or continuous data access are unavailable. These studies suggest that digital assessment should be designed as an adaptive continuum rather than as a binary choice between fully online assessment and paper-only practice.

TPACK Framework and Digital Tool Implementation. The TPACK framework (Schmidt et al., 2009) provides a lens for understanding the integrated knowledge teachers require for effective digital tool implementation. From this perspective, the key question is not whether teachers can operate devices but whether they have the integrated knowledge to select tools that fit pedagogical purposes, design appropriate tasks, and use assessment evidence effectively. Research applying this framework in developing-country contexts has found that generic ICT training is insufficient; teachers need sustained, subject-specific support in assessment design, competency rubrics, feedback strategies, digital portfolio management, inclusive participation, and large-class evidence collection.

Sociocultural Perspectives and Digital Assessment. Sociocultural learning perspectives emphasize mediation, scaffolding, interaction, and participation. From this perspective, digital tools mediate the social processes of learning and assessment. They can support communication, collaboration, and feedback, but they can also create barriers when they exclude some learners from participation. The relevant unit of analysis is not the device alone but the interaction among the learner, teacher, peer group, task, and technological artifact. Research applying this perspective has emphasized the importance of designing digital assessment that is inclusive and supports participation by all learners, regardless of their access to devices or connectivity.

Competency-Based Education Theory and Digital Assessment. Competency-Based Education Theory focuses attention on progressive mastery, authentic performance, and observable outcomes (Açıkgöz & Babadoğan, 2021). From this perspective, digital tools are relevant insofar as they support the collection of evidence about competency development. The theory emphasizes that assessment should be authentic, requiring learners to apply knowledge and skills in contexts resembling real-world situations. Digital tools can support authentic assessment through simulations, portfolios, performance tasks, and project documentation.

While these theoretical perspectives have been applied in various contexts, there is limited research that integrates them into a coherent framework for understanding and guiding digital formative assessment in resource-constrained settings. The present study addresses this gap by synthesizing these perspectives and deriving a framework that is theoretically grounded and empirically informed.

2.2.4 Development of Context-Sensitive Frameworks for Resource-Constrained Settings

The development of context-sensitive frameworks for educational technology implementation has been the subject of growing research attention. This literature emphasizes that models developed in well-connected settings commonly presume reliable electricity, adequate devices, permanent internet access, and readily available technical support. Applying such assumptions uncritically in resource-constrained settings risks producing frameworks that are conceptually attractive but operationally unusable.

Design-Based Research Approaches. Anderson and Shattuck (2012) provided a review of design-based research, emphasizing the iterative movement between evidence and design that characterizes this approach. Design-based research is particularly appropriate for framework development because it involves iterative cycles of design, implementation, analysis, and redesign that produce both practical solutions and theoretical insights. The present study employed design-based research principles in developing the RADFA Framework, moving iteratively between evidence and design to ensure contextual relevance and practical utility.

Resource-Adaptive Design. Adie et al. (2023) demonstrated the importance of designing for offline and low-resource environments. Their research showed that educational technology frameworks must account for the specific constraints of the contexts in which they will be implemented. Muhammad et al. (2023) similarly emphasized that design should begin with contextual constraints rather than ideal infrastructure assumptions. These studies suggest that frameworks for resource-constrained settings should be adaptive, allowing for different implementation pathways depending on available resources.

Contextual Implementation Factors. Studies of CBC implementation in Uganda have identified multiple contextual factors that influence framework development and implementation. Charles et al. (2023) identified teacher preparation, materials, infrastructure, assessment knowledge, and institutional support as important contextual factors. Chemutai et al. (2024) found that workload management and translation of competency expectations into evidence were

practical challenges. Kidega et al. (2024) identified training gaps, resource limitations, and institutional support as key barriers. These studies suggest that frameworks must account for the specific constraints of the context in which they will be implemented.

Gaps in Existing Frameworks. Prior studies have documented the difficulties teachers encounter when implementing competency-based curricula (Charles et al., 2023; Kidega et al., 2024; Namubiru et al., 2024; Nsengimana et al., 2024). However, much of this literature examines barriers separately, focuses on general ICT use rather than formative assessment, or evaluates curriculum implementation without modeling the relationships among enabling conditions, teacher TPACK, assessment processes, learner agency, and outcomes. The present study addresses these gaps by developing a framework that integrates these multiple dimensions and is grounded in empirical evidence from a resource-constrained setting.

III. METHODOLOGY

3.1 Research Design

The study was grounded in pragmatism because its purpose was to explain an implementation problem and develop a usable response suitable for resource-constrained lower secondary schools. Pragmatism as a research paradigm emphasizes the practical consequences of research and the integration of multiple approaches to address complex problems (Creswell & Creswell, 2023). This orientation is well-suited to educational research in developing contexts, where studies must produce knowledge that is both theoretically sound and practically applicable.

A sequential exploratory mixed-methods design was employed. This design involved two phases: an initial qualitative phase followed by a quantitative phase, with integration occurring during interpretation and framework development. The qualitative strand explored existing assessment practices, contextual barriers, enabling conditions, and stakeholder expectations through interviews, focus group discussions, non-participant observations, and document review. These insights supported interpretation of the subsequent quantitative strand, which measured the prevalence of assessment practices and relationships among the study variables. This design was appropriate because framework construction required both contextual depth and statistical evidence: qualitative data provided the contextual understanding necessary to interpret quantitative patterns meaningfully, while quantitative data provided the generalizable evidence necessary to support framework claims across the study population.

3.2 Study Area

The study was conducted in the Bukedi Sub-Region of Eastern Uganda, covering lower secondary schools in Budaka, Butaleja, Kibuku, Pallisa, Busia, and Tororo districts and the surrounding administrative context. This region was selected purposively because its schools vary considerably in location, ownership, electricity reliability, device availability, connectivity, and leadership support, making it a critical setting in which to investigate the implementation of digital formative assessment under resource constraints. The region encompasses a mix of rural, peri-urban, and urban schools, as well as government and privately owned institutions, providing variation along key contextual dimensions likely to influence digital assessment implementation. Additionally, the region had not been the focus of previous research on digital formative assessment under the Competency-Based Curriculum, offering an opportunity to contribute new empirical evidence.

3.3 Target Population

The accessible population for the study included four categories of respondents directly involved in or responsible for the implementation of the Competency-Based Lower Secondary Curriculum and digital assessment practices in the Bukedi Sub-Region.

Teachers implementing the Competency-Based Lower Secondary Curriculum constituted the first category. These teachers were responsible for designing and conducting assessment activities, providing feedback to learners, and documenting competency development. Their perspectives were central to understanding current assessment practices, the challenges of digital tool implementation, and the professional development needs associated with digital formative assessment.

Lower secondary learners constituted the second category. As the recipients of assessment practices and the primary beneficiaries of competency-based education, learners' experiences with and perceptions of assessment activities provided important evidence about the effectiveness and inclusivity of current practices. Their perspectives on digital tool use, feedback, and engagement were essential for understanding learner agency and participation in digital formative assessment.

Head teachers constituted the third category. As institutional leaders responsible for resource allocation, professional development support, and instructional supervision, head teachers' perspectives were essential for understanding the institutional enabling conditions and constraints affecting digital assessment implementation.

Policymakers, curriculum personnel, and ICT experts constituted the fourth category. These respondents brought specialized knowledge of policy expectations, curriculum design, technical infrastructure, and implementation capacity at the system level. Their perspectives were important for understanding the broader policy and technical context within which schools operate.

3.4 Sampling and Sample Size

A multi-stage sampling procedure was employed to select schools and respondents for the study.

School Sampling. Schools were stratified by two contextual characteristics: location (rural, peri-urban, urban) and ownership (government, private). These strata were selected because prior research suggested they are associated with differences in resource availability, infrastructure, and implementation capacity (Charles et al., 2023; Chemutai et al., 2024). Within each stratum, schools were selected using probability proportional to size, with larger schools having proportionally greater representation. This ensured that the sample reflected the distribution of schools and learners across the sub-region. A total of 47 schools were selected for the study, distributed across the six districts in proportion to the number of schools in each district.

Teacher Sampling. Within selected schools, teachers were sampled using systematic random sampling from the list of teachers teaching lower secondary classes under the Competency-Based Curriculum. In schools with fewer than five eligible teachers, all teachers were included. This approach yielded a target sample of 200 teachers.

Student Sampling. Within selected schools, students were sampled using systematic random sampling from class registers of lower secondary classes (Senior 1 to Senior 4). Students were sampled in proportion to class size, with larger classes contributing more students to the sample. This approach yielded a target sample of 500 students.

Head Teacher Sampling. Head teachers of selected schools were included automatically as key informants within their institutions. With 47 selected schools, this yielded a target sample of 47 head teachers.

Policymaker and Expert Sampling. Policymakers, curriculum personnel, and ICT experts were selected purposively because of their specialized roles and knowledge of the policy, curriculum, and technical dimensions of digital assessment implementation. Selection criteria included direct involvement in CBC policy development, curriculum design, ICT infrastructure planning, or teacher professional development at the district or national level. This yielded a target sample of 20 policymakers and experts.

Sample Size Achievement. A total of 770 questionnaires were distributed through the study, and 743 usable responses were returned, giving an overall response rate of 96.5%. The achieved sample comprised 193 teachers, 486 students, 47 head teachers, and 17 policymakers or ICT experts. This sample size exceeded the minimum required for multiple regression analysis, which generally requires at least 20 cases per predictor variable (Field, 2024). With 193 teacher responses and four predictor variables, the study had adequate statistical power to detect meaningful relationships.

Table 1

Response Profile

Respondent category	Distributed	Returned	Non-response	Response rate (%)
Teachers	200	193	7	96.5
Students	500	486	14	97.2
Head teachers	50	47	3	94.0
Policymakers/ICT experts	20	17	3	85.0
Total	770	743	27	96.5

Source: Field Data (2026)

3.5 Data Collection Instruments and Procedures

The study employed multiple instruments to collect data from different respondent categories and to enable triangulation across sources.

Questionnaires. Structured questionnaires were developed for each respondent category: teachers, students, head teachers, and policymakers/ICT experts. Each questionnaire comprised five-point Likert-type items ranging from 1 (strongly disagree) to 5 (strongly agree). The teacher questionnaire measured the following constructs: assessment methods used (including traditional, competency-based, and digital methods); infrastructure and digital-tool availability; teacher digital literacy; curriculum requirements; school leadership support; teacher TPACK; formative assessment processes; and perceived competency outcomes. The student questionnaire measured learner agency, engagement, and perceived competency outcomes. The head teacher questionnaire measured institutional support, infrastructure, and implementation leadership. The policymaker and ICT expert questionnaire measured policy expectations, resource allocation, technical support systems, and implementation capacity.

Semi-Structured Interview Guides. Semi-structured interview guides were developed for teachers, head teachers, policymakers, and ICT experts. These guides explored how digital tools were being used in assessment, what constraints respondents faced, what forms of support were available, what stakeholders considered necessary in a context-sensitive framework, and what components such a framework should include. The semi-structured format allowed for flexibility in probing emergent themes while ensuring consistent coverage of key topics across interviews.

Focus Group Discussion Guides. Focus group discussion guides explored similar themes as the interview guides but were designed for group interaction, allowing participants to build on and challenge one another's perspectives. The focus groups were particularly useful for identifying shared challenges and collective solutions that might not emerge in individual interviews. A total of eight focus groups were conducted: two with teachers (10-12 participants each), two with students (10-12 participants each), two with head teachers (6-8 participants each), and two with policymakers and ICT experts (5-7 participants each).

Non-Participant Observation Protocols. Non-participant observation protocols examined infrastructure, tool functionality, assessment routines, learner interaction with digital tools, and the handling of technical disruptions. Observations were conducted in a subset of 15 schools representing rural, peri-urban, and urban locations and government and private ownership. Each observation session lasted approximately two hours and focused on a single classroom or computer laboratory session. Observers recorded field notes on the physical environment, available technology, teacher and learner activities, assessment practices, and any technical issues encountered.

Document Review Protocols. Document review protocols guided the examination of curriculum documents, institutional assessment policies, school ICT plans, teacher training materials, and administrative records. These documents were reviewed to triangulate self-reported practice and to understand the policy and institutional context within which digital assessment decisions were being made.

Quality Control Procedures. Several procedures ensured the quality of the data collection instruments. First, experts reviewed the instruments for content alignment, clarity, and relevance. The review panel included two educational assessment specialists, two educational technology experts, and three practicing teachers familiar with CBC implementation. Based on their feedback, items were revised for clarity and relevance. Second, pilot testing preceded the main data collection. The instruments were piloted in a purposively selected non-sample school representing the contextual characteristics of the target population. The pilot involved 15 teachers, 30 students, and the head teacher. Based on pilot results, unclear items were revised, and the estimated completion time for each instrument was confirmed. The pilot also tested the logistical arrangements for data collection, including instrument administration procedures and data management protocols. Third, triangulation across questionnaires, interviews, focus groups, observations, and documents strengthened the credibility of the findings. An audit trail linked themes and framework components to the underlying evidence, ensuring that the framework was grounded in empirical data rather than researcher speculation.

Framework Development and Validation Procedures. The development of the Resource-Adaptive Digital Formative Assessment (RADFA) Framework followed a systematic process grounded in the empirical evidence collected through the study. This process comprised five stages:

Stage 1: Identification of Candidate Components. Candidate framework components were identified from three sources: (a) the theoretical literature on formative assessment, TPACK, sociocultural learning, and competency-based education; (b) prior empirical studies of CBC implementation and digital tool use in Ugandan and similar contexts; and (c) qualitative themes emerging from the interviews, focus groups, observations, and document review conducted in the present study. This stage produced a preliminary set of components organized into functional categories: infrastructure and support, teacher capacity, assessment processes, learner participation, and outcomes.

Stage 2: Empirical Examination of Candidate Components. The candidate components were empirically examined through quantitative analysis. Availability of digital tools, teacher digital literacy, curriculum requirements, and school leadership support were measured using the questionnaire items. Their relationships to CBC-aligned assessment effectiveness were assessed through descriptive statistics, correlation analysis, and multiple regression. Teacher TPACK and learner agency were measured through separate questionnaire scales. These quantitative analyses provided statistical evidence for the relevance and predictive power of each component and for the relationships among components.

Stage 3: Synthesis of Relationships. The relationships among components were synthesized across the quantitative and qualitative strands. Quantitative patterns (e.g., which predictors significantly contributed to assessment effectiveness, the strength of those contributions, location-based differences) were interpreted in light of qualitative themes (e.g., why leadership matters for implementation, what forms of digital support are needed, how resource constraints operate in practice). This synthesis identified the key pathways through which enabling conditions, teacher capacity, assessment processes, learner participation, and outcomes are connected. It also identified the adaptive responses that schools were using to address resource constraints, which informed the framework's resource-adaptive logic.

Stage 4: Construction of the Visual Model. The synthesized components and relationships were organized into a visual model representing the RADFA Framework. The visual model depicts the functional components and their interconnections, including the feedback loops through which assessment evidence informs improvement. The model was refined through multiple iterations, with each version reviewed for coherence, completeness, and clarity.

Stage 5: Validation of the Framework. The framework was validated against relevance, coherence, practicality, and contextual applicability criteria. Validation involved three procedures. First, the framework was presented to stakeholders (including practicing teachers, head teachers, and ICT experts who participated in the study) for feedback on its relevance and practicality. This stakeholder validation was conducted through two validation workshops with a total of 24 participants. Second, the framework was reviewed by three experts in educational assessment, educational technology, and curriculum studies, who assessed its coherence and theoretical grounding. Third, the framework was applied to the case study data from the schools visited during the study to assess its applicability and explanatory power. This iterative movement between evidence and design is consistent with design-based research principles (Anderson & Shattuck, 2012).

3.6 Data Analysis

Quantitative Analysis. Quantitative data from the questionnaires were coded, cleaned, and analyzed using descriptive and inferential statistics. Frequencies, percentages, means, and standard deviations summarized the assessment methods and study constructs. One-way analysis of variance (ANOVA) tested differences in CBC-aligned assessment effectiveness across rural, peri-urban, and urban schools. When the ANOVA was significant, Tukey post hoc comparisons were used to identify which location groups differed significantly. Pearson correlation assessed associations among the predictors (digital-tool availability, digital literacy, curriculum requirements, and leadership support) and assessment effectiveness. Multiple linear regression estimated the joint and individual contribution of the four predictors to CBC-aligned assessment effectiveness. Statistical significance was evaluated at $\alpha = .05$, following standard procedures for applied statistical analysis (Field, 2024). All quantitative analyses were conducted using IBM SPSS Statistics version 27.

The regression model was specified as:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \varepsilon$$

where:

- Y represented CBC-aligned assessment effectiveness (the dependent variable, measured as a composite score of teacher responses to items on competency-based and digital assessment practices);
- X_1 represented availability of digital tools (measured as a composite score of teacher responses to items on device access, connectivity, and infrastructure);
- X_2 represented digital literacy (measured as a composite score of teacher responses to items on ability to use digital tools for educational purposes);
- X_3 represented curriculum requirements (measured as a composite score of teacher responses to items on curriculum expectations for digital assessment);
- X_4 represented school leadership support (measured as a composite score of teacher responses to items on leadership engagement, resource allocation, and monitoring of digital assessment).

Assumptions for multiple regression were checked prior to analysis. Linearity was assessed through scatterplots of residuals against predicted values. Normality of residuals was assessed through histograms and P-P plots. Homoscedasticity was assessed through scatterplots of standardized residuals against standardized predicted values. Independence of errors was assessed through the Durbin-Watson statistic. Multicollinearity was assessed through variance inflation factors (VIF) and tolerance statistics. All assumptions were met.

Qualitative Analysis. Qualitative data from interviews, focus groups, observations, and document review were transcribed, read repeatedly, coded, and organized into themes following the systematic procedures of thematic analysis (Braun & Clarke, 2022). The analysis followed six phases: familiarization with the data, generation of initial codes, searching for themes, reviewing themes, defining and naming themes, and producing the report. Coding was inductive, with codes emerging from the data rather than being imposed from prior theory, though the theoretical framework informed the interpretation of themes. Inter-coder reliability was assessed by having two researchers independently code a subset of transcripts; agreement was high ($\kappa = .87$), indicating reliable coding. Themes were organized around the study objectives: current assessment practices, factors influencing digital tool implementation, theoretical perspectives on implementation, and framework components.

Integration. Quantitative patterns, qualitative themes, theoretical constructs, and contextual observations were synthesized to derive and validate the framework components. Integration occurred at multiple points: during instrument development (where qualitative findings from piloting informed item refinement), during analysis (where quantitative patterns were interpreted in light of qualitative themes), and during framework development (where evidence from both

strands was synthesized into the final framework). This integrated approach ensured that the framework was both empirically grounded and contextually relevant.

3.7 Ethical Considerations

Ethical approval for the study was obtained from the institutional research ethics committees of Masinde Muliro University of Science and Technology and Busitema University, as well as from the Uganda National Council for Science and Technology. Permission to conduct research in schools was obtained from the Ministry of Education and Sports and from individual school authorities.

Informed Consent. Participants received information about the study's purpose and procedures and provided informed consent. For student participants under 18 years, parental consent was obtained in addition to student assent. Information sheets were provided in English and, where necessary, translated into local languages to ensure comprehension. Participants were informed that their participation was voluntary and that they could withdraw at any time without penalty.

Confidentiality and Anonymity. Identifying information was removed from the analytical records and reported quotations. School and participant names were replaced with pseudonyms in all reports to protect anonymity. Data were handled confidentially and used for the stated research purpose.

Data Storage and Security. Data were stored securely, with access limited to the research team. Paper records were stored in locked cabinets, and digital records were stored on password-protected computers. Data will be retained for five years following the study's completion and then securely destroyed.

Benefit and Harm. The study was designed to minimize any potential harm or inconvenience to participants. Data collection was scheduled to minimize disruption to school activities. Participants were not compensated for their participation, as this could have created undue influence. The study was designed to generate knowledge that would benefit teachers, schools, and the broader education system by supporting more effective implementation of the Competency-Based Curriculum.

IV. RESULTS AND DISCUSSION

4.1 Current Assessment Methods

The findings show that curriculum reform has not yet displaced examination-oriented assessment. Traditional methods recorded an overall mean of 3.94 (SD = 0.83). Written examinations were most prominent (M = 4.12, SD = 0.76), followed by continuous testing (M = 4.01, SD = 0.80), assignment-based assessment (M = 3.88, SD = 0.85), and oral assessment (M = 3.75, SD = 0.90). In contrast, the combined competency-based and digital category recorded a mean of 2.90 (SD = 1.07). Project-based assessment was the most established method in this category (M = 3.22, SD = 1.01), followed by performance-based assessment (M = 3.06, SD = 1.02), portfolio assessment (M = 2.84, SD = 1.11), and digital assessment (M = 2.47, SD = 1.15).

Table 2

Reported Use of Assessment Methods

Assessment Category or Method	Mean	SD
Traditional assessment methods (overall)	3.94	0.83
Written examinations	4.12	0.76
Continuous testing	4.01	0.80
Assignment-based assessment	3.88	0.85
Oral assessment	3.75	0.90
Competency-based and digital methods (overall)	2.90	1.07
Project-based assessment	3.22	1.01
Performance-based assessment	3.06	1.02
Portfolio assessment	2.84	1.11
Digital assessment	2.47	1.15

Source: Field data (2026). Scale: 1 = strongly disagree to 5 = strongly agree.

This pattern reveals a transitional assessment system. Teachers are not relying solely on end-of-term examinations; class tests, quizzes, assignments, questioning, and discussion are common. Nevertheless, these practices remain easier to administer and record than portfolios, authentic performance tasks, digital competency profiles, or continuous learner analytics. The result is continuous assessment in frequency without an equivalent transformation in the type of evidence collected.

Qualitative evidence reinforced this interpretation. One head teacher stated that “most teachers still use written exercises and tests because they are familiar with them,” while a focus-group participant explained that practical assessment was undertaken only occasionally because of time and resource constraints. Observations similarly found that exercise books, written tests, and manually maintained records constituted the most visible forms of assessment evidence. These findings are consistent with Ugandan studies reporting that teachers support CBC goals but struggle with workload, resources, assessment design, and the persistence of examination expectations (Chemutai et al., 2024; Kidega et al., 2024; Namubiru et al., 2024).

Digital assessment’s low mean shows that general exposure to ICT has not yet become a coherent cycle of electronic assessment, progress tracking, feedback, and portfolio use. Access and adoption are therefore distinct: possessing a computer laboratory or smartphone does not ensure its routine assessment use.

4.2 Location-Based Differences in Assessment Effectiveness

CBC-aligned assessment effectiveness differed significantly by school location, $F(2, 190) = 12.13, p < .001$. Peri-urban schools recorded the highest mean ($M = 4.22, SD = 0.89$), followed by urban schools ($M = 4.13, SD = 0.76$), while rural schools recorded the lowest mean ($M = 3.51, SD = 0.99$). Tukey post hoc comparisons indicated significant differences between peri-urban and rural schools (mean difference = 0.70, $p = .003$) and between urban and rural schools (mean difference = 0.62, $p < .001$). Peri-urban and urban schools did not differ significantly ($p = .924$).

Table 3

Differences in CBC-Aligned Assessment Effectiveness by School Location

School location	n	Mean	SD	ANOVA
Peri-urban	23	4.22	0.89	$F(2, 190) = 12.13$ $p < .001$
Rural	103	3.51	0.99	
Urban	67	4.13	0.76	

Source: Field data (2026).

Participants attributed the rural disadvantage to overlapping constraints in connectivity, devices, maintenance, power, teacher exposure, and technical support. As one ICT coordinator observed, some computer laboratories had “the number of devices is far below the student population.” The location effect therefore represents clustered disadvantage rather than geography alone. A uniform national expectation can reproduce inequity unless support is differentiated; offline platforms, local storage, backup power, shared-device designs, and school-based support can narrow the gap (Adie et al., 2023; Muhammad et al., 2023).

4.3 Determinants of CBC-Aligned Assessment Effectiveness

Pearson correlations showed positive associations between assessment effectiveness and digital literacy ($r = .293, p < .001$), curriculum requirements ($r = .407, p < .001$), and school leadership support ($r = .598, p < .001$). Leadership support had the strongest bivariate relationship. The regression model that included digital-tool availability, digital literacy, curriculum requirements, and leadership support was statistically significant, $R = .739, R^2 = .546$, adjusted $R^2 = .537, F(4, 188) = 56.58, p < .001$. The four predictors therefore explained 54.6% of the variance in teacher-reported CBC-aligned assessment effectiveness.

Table 4

Multiple Regression Predicting CBC-Aligned Assessment Effectiveness

Predictor	B	SE	β	t	p
Constant	-.209	.314	—	-.664	.507
Availability of digital tools	.395	.060	.343	6.583	< .001
Digital literacy	.198	.064	.171	3.100	.002
Curriculum requirements	.062	.072	.052	.861	.391
School leadership support	.517	.057	.523	9.010	< .001

Model: $R = .739, R^2 = .546$; adjusted $R^2 = .537, F(4, 188) = 56.58, p < .001, n = 193$.

Source: Field data (2026).

School leadership support was the strongest predictor ($B = .517, \beta = .523, p < .001$). Availability of digital tools was also substantial and significant ($B = .395, \beta = .343, p < .001$), while digital literacy made a smaller but significant contribution ($B = .198, \beta = .171, p = .002$). Curriculum requirements were not statistically significant after the practical implementation variables were controlled ($B = .062, \beta = .052, p = .391$). The null hypothesis was therefore rejected for the model as a whole, although curriculum requirements did not independently predict effectiveness.

The leadership result moves the discussion beyond infrastructure. Leaders determine whether resources are budgeted, maintained, scheduled, monitored, and connected to assessment priorities, and whether teachers receive time, coaching, peer learning, and permission to experiment. A head teacher explained that without leadership commitment, “resources and support structures will not be prioritized.” This accords with evidence that policy intentions do not transform practice when institutional support and teacher capacity are weak (Charles et al., 2023; Kidega et al., 2024). The non-significant curriculum coefficient reinforces the distinction between policy expectation and implementation capacity: explicit procedures, usable tools, trained teachers, supported experimentation, and accountable leadership are needed to translate curriculum language into practice.

4.4 Teacher TPACK and Learner Agency

Teachers reported a strong overall TPACK mean of 4.02. High indicators included learning technology easily ($M = 4.38$, $SD = 0.92$), integrating technology, pedagogy, and content ($M = 4.13$, $SD = 0.85$), and using digital tools for otherwise difficult competency assessment ($M = 3.95$, $SD = 1.09$). The lower score for choosing technology to enhance a specific teaching approach ($M = 3.66$, $SD = 1.25$) distinguished general confidence from pedagogically precise selection.

Students also reported confidence with digital devices ($M = 3.98$, $SD = 0.88$), motivation ($M = 4.05$, $SD = 0.97$), responsibility for acting on digital feedback ($M = 3.91$, $SD = 0.92$), and initiative ($M = 3.84$, $SD = 0.82$). Peer-feedback use was weaker ($M = 3.60$, $SD = 0.97$), indicating that individual participation is better established than reciprocal assessment.

Table 5

Selected Teacher TPACK and Learner-Agency Indicators

Indicator	Mean	SD
Teachers: learn technology easily	4.38	0.92
Teachers: integrate technology, pedagogy, and content	4.13	0.85
Teachers: use digital tools for otherwise difficult competency assessment	3.95	1.09
Teachers: select technology that enhances a teaching approach	3.66	1.25
Students: confidence using digital devices	3.98	0.88
Students: motivation when using digital tools	4.05	0.97
Students: responsibility for improvement from digital feedback	3.91	0.92
Students: use digital tools for peer feedback	3.60	0.97

Scale: 1 = strongly disagree to 5 = strongly agree.

Source: Field Data (2026).

These results support the TPACK proposition that meaningful integration occurs at the intersection of technology, pedagogy, and content (Schmidt et al., 2009). They also reveal why generic ICT training is insufficient. Teachers may be able to operate devices and learn applications but still need sustained, subject-specific support in assessment design, competency rubrics, feedback strategies, digital portfolio management, inclusive participation, and large-class evidence collection. A teacher observed that many colleagues could use smartphones but lacked the specialized skills required for digital assessment systems. Professional development should therefore focus on assessment decisions rather than software demonstrations alone.

Learner agency functions as a mediating condition. Digital tools can make feedback immediate and progress visible, but learners must interpret that feedback, set goals, revise work, collaborate, and assume responsibility for improvement. Peer and self-assessment deserve particular attention because they are central to formative assessment yet remain less established than teacher-directed uses. The results align with Black and Wiliam’s (2009) emphasis on activating learners as owners of their learning and as resources for one another.

4.5 Development of the RADFA Framework

Framework development followed five stages: identification of components from literature, theory, and qualitative themes; empirical examination of the components; synthesis of relationships across the quantitative and qualitative strands; construction of a visual model; and validation against relevance, coherence, practicality, and contextual applicability. This iterative movement between evidence and design is consistent with design-based research principles (Anderson & Shattuck, 2012). Five functional components were retained.

First, resource-adaptive digital assessment infrastructure and institutional support form the foundation. This component includes leadership, devices, connectivity, sustainable power, technical support, curriculum guidance, partnerships, offline platforms, and local servers. Second, teacher digital pedagogical capacity converts resources into instructionally meaningful practice through TPACK, assessment design, tool selection, troubleshooting, and

professional learning. Third, digital formative assessment processes operationalize the model through feedback, competency tracking, learner monitoring, digital portfolios, varied assessment methods, and personalized support. Fourth, learner engagement and student agency connect evidence to reflection, peer learning, self-regulation, and ownership. Fifth, competency development outcomes include critical thinking, problem-solving, communication, collaboration, creativity, and demonstrated curriculum mastery. A continuous improvement loop returns assessment evidence to teacher adjustment, learner support, infrastructure planning, school decision-making, and curriculum refinement.

Table 6
Resource Constraints and Adaptive Responses in the RADFA Framework

Constraint	Adaptive response	Assessment benefit
Unreliable electricity	Solar systems, generators, or inverters	Continuity of assessment activities
Limited internet	Offline-first platforms and local servers	Assessment and feedback without permanent connectivity
Inadequate devices	Shared-device groups, rotations, and phased procurement	Broader learner access
Limited funding	Public-private and NGO partnerships	Sustainable acquisition and maintenance
Large classes	Digital tracking and automated records	More efficient learner monitoring
Technical-support gaps	School-based digital champions and peer support	Reduced disruption and faster recovery

Source: Authors' synthesis from the study findings (2026)

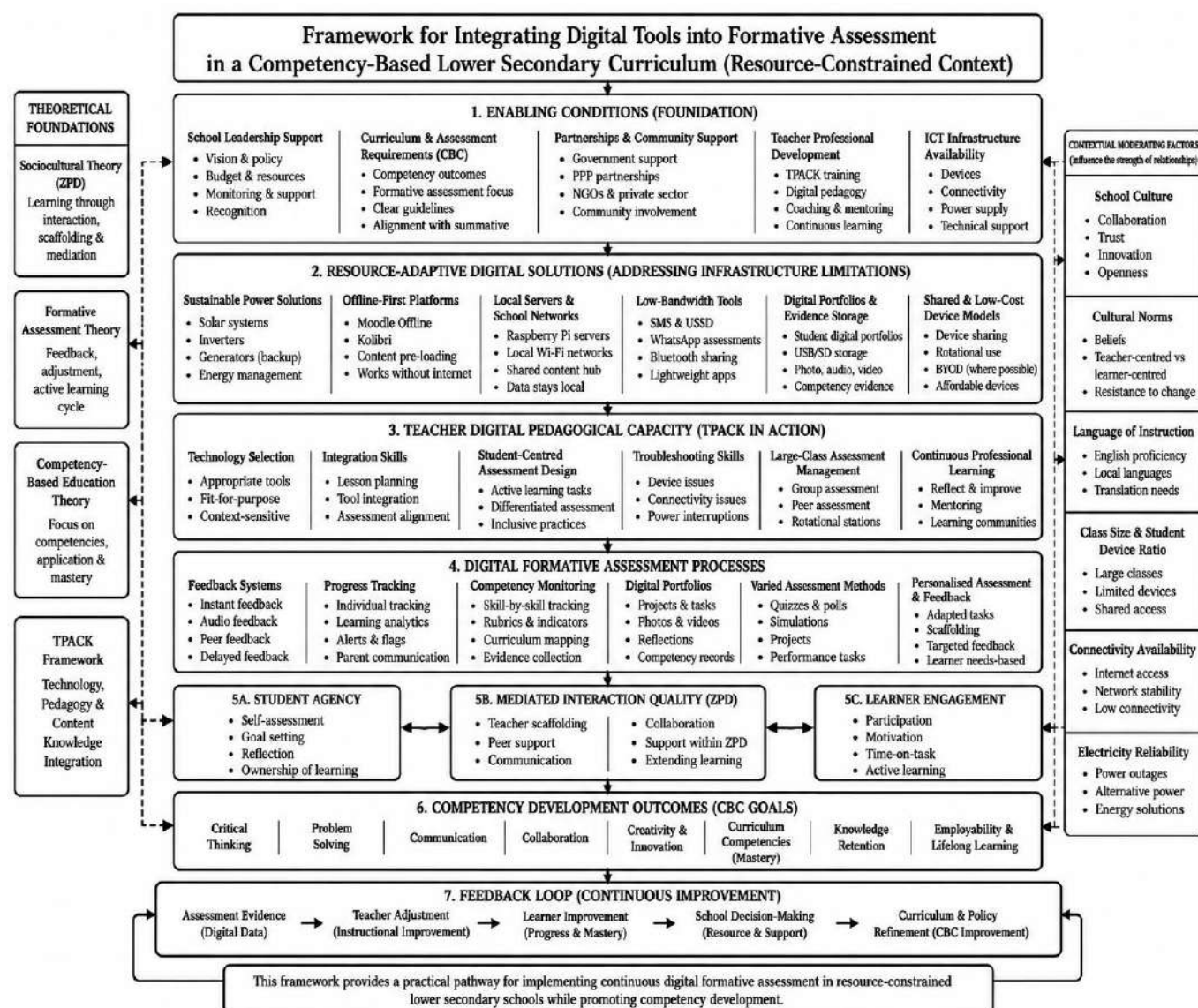


Figure 2
Resource-Adaptive Digital Formative Assessment (RADFA) Framework.
Source: Framework developed from the study findings (2026).

The framework's distinctive contribution is its resource-adaptive logic. It does not postpone digital formative assessment until every school has broadband and one device per learner. Instead, it asks what assessment functions must be achieved and selects the lowest-dependency technology capable of achieving them reliably. A teacher may use an offline quiz synchronized later, a local spreadsheet for competency tracking, audio feedback delivered through shared devices, a USB-based portfolio, or an SMS alert where bandwidth is limited. More advanced online functions can be added as infrastructure improves.

This approach also avoids technological determinism. The regression results show that leadership and tool availability matter, but the TPACK and learner-agency findings show how those resources become educationally productive. Technology is positioned as a mediator of evidence, interaction, feedback, and reflection rather than as an outcome in itself. The final criterion remains competency development.

4.6 Implications for Policy and Practice

For school leaders, the findings support the establishment of a school-level digital formative assessment plan with defined priorities, responsibilities, maintenance arrangements, teacher-learning schedules, and monitoring indicators. Investment decisions should begin with the assessment problem to be solved rather than the novelty of the device. Leaders should protect time for teachers to design and review digital assessments, support peer coaching, and use assessment evidence in instructional meetings.

For teachers, the framework provides a sequence for implementation. Teachers can begin by clarifying the competency and evidence required, selecting an accessible tool, deciding how feedback will be generated and acted upon, and ensuring that learners can participate equitably. Digital portfolios and simple competency-tracking records are particularly useful because they preserve evidence over time and support progress conversations. Peer and self-assessment should be deliberately designed rather than assumed to emerge from device use.

For policymakers and curriculum implementers, the results indicate that curriculum requirements need operational guidance and differentiated resourcing. Standards should specify acceptable offline and low-bandwidth approaches, minimum evidence requirements, data-protection expectations, and realistic models for large classes and shared devices. Rural schools require targeted infrastructure and professional support if national digital-assessment expectations are to be equitable.

For development partners and the private sector, the framework identifies priority investments with direct assessment value: sustainable power, offline-first platforms, local servers, affordable devices, competency-record systems, teacher development, and school-based technical support. Partnerships should include maintenance, capacity transfer, and long-term operating costs rather than focusing only on initial equipment delivery.

V. CONCLUSION & RECOMMENDATIONS

5.1 Conclusion

The study demonstrates that lower secondary assessment in Bukedi remains in transition. Traditional methods are firmly established, while portfolio, performance-based, and digital assessment practices are less consistent. The rural assessment-effectiveness gap confirms that implementation is conditioned by unequal access to infrastructure and support. The regression model further shows that school leadership, tool availability, and teacher digital literacy not curriculum requirements in isolation drive effective CBC-aligned assessment.

The evidence supports a systemic rather than device-centred response. Teachers reported strong foundations in TPACK, and students reported confidence and motivation, but practical gaps remain in tool selection, peer assessment, troubleshooting, connectivity, device ratios, and sustained implementation. The RADFA Framework responds by linking adaptive infrastructure and institutional support to teacher capacity, formative assessment processes, learner agency, competency outcomes, and continuous improvement. Its central proposition is that digital formative assessment can be implemented under resource constraints when technology choices are aligned with assessment purposes and supported by leadership, teacher learning, and context-sensitive infrastructure.

5.2 Recommendations

The findings of this study carry implications for multiple stakeholders in Uganda's education system. The empirical evidence that leadership support was the strongest predictor of CBC-aligned assessment effectiveness suggests that school leaders should take a more active role in digital formative assessment implementation. Rather than treating technology integration as a technical matter best left to ICT teachers or external experts, school leaders should adopt explicit digital formative assessment plans that define priorities, allocate resources for maintenance and technical support, protect time for teacher professional development, and monitor implementation as part of their instructional leadership responsibilities. The evidence that rural schools reported significantly lower assessment effectiveness than

peri-urban and urban schools further suggests that leadership support in these settings may be particularly consequential; leaders in rural schools should be prioritized for professional development on leading digital assessment implementation and should receive differentiated support to address the resource constraints their schools face.

Teacher professional development should move beyond basic digital literacy to address the specific knowledge and skills teachers need for digital formative assessment. The TPACK findings indicated that teachers reported strong general confidence with technology but weaker capacity to select technology that enhances a specific teaching approach or assessment purpose. This suggests that professional development should focus on assessment design, feedback strategies, digital portfolio management, competency tracking, peer and self-assessment facilitation, and strategies for collecting evidence in large classes. Professional development should be sustained rather than one-off, and should incorporate peer learning, coaching, and opportunities for teachers to practice with the tools they will be expected to use. The non-significant contribution of curriculum requirements to assessment effectiveness, after controlling for other variables, suggests that curriculum expectations alone do not drive change; professional development must therefore bridge the gap between curriculum language and classroom practice by providing concrete guidance and practical examples.

The location-based differences in assessment effectiveness, with rural schools significantly below peri-urban and urban schools, underscore the need for differentiated resource allocation. Rural and resource-constrained schools should be prioritized for solar or backup power systems, offline-first platforms, local servers, shared-device models, and school-based digital champions. These investments should not be limited to initial equipment delivery; they should include ongoing support for maintenance, troubleshooting, and capacity building. Partnerships with private sector organizations, non-governmental organizations, and development partners can help mobilize resources, but these partnerships should include commitments to long-term operating costs rather than focusing only on equipment. The resource-adaptive responses identified in the study offline platforms, solar power, shared devices, school-based champions offer practical models that can be scaled across similar contexts.

Curriculum authorities should provide practical standards for digital and offline evidence collection under the CBC. The non-significant contribution of curriculum requirements to assessment effectiveness suggests that policy expectations are not yet translating into practice; this translation requires operational guidance that addresses implementation realities. Such guidance should specify minimum evidence requirements, acceptable offline and low-bandwidth approaches, data-protection expectations, and realistic models for large classes and shared devices. It should also include examples of competency records, feedback cycles, and equitable participation strategies that can be implemented under resource constraints. This guidance should be developed in consultation with teachers and school leaders who understand the practical challenges of implementation and should be accompanied by professional development and monitoring systems.

Schools should consider piloting the RADFA Framework incrementally, beginning with a small number of teachers or classes and using the continuous improvement loop to refine tools, teacher support, infrastructure, and learner participation. The framework's resource-adaptive logic selecting the lowest-dependency technology capable of achieving the required assessment function reliably offers a practical starting point for schools that may have limited resources. Schools can begin by clarifying the competencies and evidence required, selecting accessible tools, deciding how feedback will be generated and acted upon, and ensuring that learners can participate equitably. Schools should review assessment evidence each term and use that evidence to inform improvements to tools, professional development, infrastructure, and learner participation strategies. This incremental, evidence-based approach reduces the risk of investing in technology that does not support assessment purposes and allows schools to build capacity over time.

Future research should test the framework longitudinally to examine changes in observed learner competencies and to evaluate cost, usability, sustainability, and transferability across other Ugandan regions and similar contexts. Longitudinal studies could assess whether schools implementing the framework show greater improvement in assessment effectiveness and competency outcomes than comparison schools. Cost-effectiveness studies could inform investment decisions by identifying which framework components yield the greatest improvement per unit of investment. Usability studies could identify implementation challenges and inform refinements to the framework and associated professional development. Transferability studies could assess whether the framework requires adaptation for different regions, school types, or levels of education. Additionally, research is needed on the specific forms of leadership support that are most effective in promoting digital formative assessment, the relationship between digital assessment practices and learner performance on competency-based assessments, and the conditions under which peer and self-assessment are most effectively supported through digital tools.

Declaration of Interest

The authors declare that they do not have any known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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