Information and communication technologies [ICT] and competency-based education in developing economies: A critical review of adoption models, outcomes, and implications for East Africa

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ABSTRACT

Developing economies increasingly rely on Information and Communication Technologies (ICT) to transform education systems, coinciding with a shift toward Competency-Based Education (CBE), a reform agenda focused on learning outcomes and skills acquisition. In East Africa, national policies link ICT adoption with CBE goals, envisioning technology as a vehicle for equitable, personalized, and skills-oriented learning. However, evidence connecting ICT integration to actual competency development remains limited and inconsistent. This review is theoretically grounded in three complementary frameworks: the Technology Acceptance Model (TAM) and the Unified Theory of Acceptance and Use of Technology (UTAUT), which explain individual and organizational drivers of ICT adoption, and the Technological Pedagogical Content Knowledge (TPACK) framework, which illuminates the integrated competencies teachers require to leverage technology for effective, content-specific instruction. Drawing on these frameworks, the review examines ICT adoption trends, theoretical models, and empirical evidence from thirty-seven peer-reviewed studies focused on Kenya, Tanzania, Rwanda, and Uganda. Through systematic analysis of technology adoption patterns, pedagogical practices, and implementation challenges, the study identifies persistent gaps in infrastructure, teacher preparedness, assessment capacity, and outcome-focused evaluation. The findings reveal a critical disconnect between technology availability and educational outcomes, particularly in low-resource settings where connectivity, teacher training, and institutional capacity remain uneven. In response, the review advances a set of actionable recommendations. First, it calls for reorienting ICT investments toward outcome-oriented integration, prioritizing interventions that explicitly link technology use to competency development, formative assessment, and authentic performance tasks. Second, it recommends systematic, TPACK-informed teacher professional development, moving beyond basic digital skills to sustained, subject-specific support that enables teachers to design and facilitate competency-based, and technology-enhanced learning. Third, it proposes innovation in digital assessment systems, including the development and piloting of ICT-enabled formative and adaptive assessments aligned with CBE frameworks. Fourth, it urges context-sensitive policies and implementation strategies, such as targeted support to rural and underserved schools, school-level leadership development, and mechanisms for monitoring and evaluating ICT-CBE initiatives using robust learning outcome indicators. By synthesizing fragmented evidence, critiquing existing theoretical frameworks for developing-economy contexts, and articulating this research and policy agenda, the review provides concrete guidance for policymakers, educators, and researchers seeking to align ICT investments with competency-based educational transformation in East Africa.

Keywords: Assessment Practices, Competency-Based Education, Digital Literacy, East Africa, Educational Technology, ICT in Education, Learning Outcomes, Pedagogical Innovation, Teacher Capacity, Technology Adoption

I. INTRODUCTION

Over the past two decades, Information and Communication Technologies (ICT) have fundamentally transformed education systems globally, reshaping how knowledge is created, disseminated, and assessed. In developed economies, technologies such as digital learning platforms, virtual reality, artificial intelligence-driven assessments, and adaptive learning systems support flexible, interactive, and personalized learning experiences. These tools facilitate content delivery, enable real-time monitoring of learner progress, support collaborative engagement, and encourage active participation in knowledge construction. The integration of ICT has moved beyond simple digitization of content to encompass sophisticated learning analytics, adaptive algorithms that personalize instruction and immersive technologies that create experiential learning environments [1].

In developing economies, particularly in Sub-Saharan Africa, ICT adoption in education has accelerated dramatically, driven by policy reforms, donor investments, and the proliferation of mobile technologies. The rapid expansion of mobile network coverage, declining costs of devices and increasing internet penetration have created unprecedented opportunities for educational transformation. Governments in Kenya, Tanzania, Rwanda, and Uganda have launched ambitious digital education initiatives, including the Digital Literacy Programme in Kenya, the Tanzania Education and Skills for Transformation (BEST) Programme, Rwanda's Smart Classroom Initiative, and Uganda's ICT in Education Policy. These initiatives aim to bridge the digital divide, improve access to quality education, and prepare learners for the demands of a globalized, technology-driven economy. The initiatives reflect a broader recognition that digital literacy and technology-mediated learning are essential for economic competitiveness and social development in the 21st century [2], [3].

Parallel to ICT expansion, East African countries have adopted Competency-Based Education (CBE) frameworks that emphasize learning outcomes, practical skills, and learner-centered pedagogy over traditional content-focused instruction. CBE represents a fundamental shift from time-based to mastery-based progression, where learners advance upon demonstrating competence rather than completing a fixed duration of instruction. This approach prioritizes what learners can demonstrate, including cognitive skills, practical abilities, and behavioural competencies, rather than what they have been taught. CBE frameworks align education with labour market needs and 21st-century skill requirements, emphasizing critical thinking, problem-solving, collaboration, communication, and creativity. The convergence of ICT and CBE represents a strategic opportunity to leverage technology for personalized learning, formative assessment, and skills development. Technology can enable adaptive learning pathways, provide immediate feedback, facilitate competency tracking, and support diverse learning modalities that accommodate different learning styles and paces [4], [5].

Despite policy enthusiasm and substantial investments in both ICT infrastructure and CBE reforms, the relationship between ICT adoption and competency development remains underexplored. Most studies focus on technology access, infrastructure deployment, or user acceptance, with limited attention to pedagogical transformation or learning outcomes. Research has documented improvements in device availability, internet connectivity, and user adoption rates, but evidence linking these inputs to enhanced teaching practices or improved student competencies is scarce. The gap between technology availability and educational impact raises critical questions about the effectiveness of current ICT integration strategies in supporting CBE objectives. This disconnect suggests that technology alone is insufficient for educational transformation and that attention must shift to how technology is used, the pedagogical models it supports, and the capacity of educators to leverage it effectively [6], [7].

1.1 Statement of the Problem

East African education systems face a fundamental paradox: while ICT infrastructure and access have expanded significantly, evidence of meaningful pedagogical transformation and competency development remains weak. Several interconnected challenges undermine the potential of ICT to support CBE objectives. First, infrastructure deficits persist across the region. Unreliable electricity supply, particularly in rural areas, limits device charging and internet connectivity. Limited internet connectivity, characterized by low bandwidth and excessive costs, restricts access to online resources. Insufficient hardware, including outdated computers and inadequate device-to-student ratios, further constrains technology use. These challenges are most acute in rural and underserved areas, exacerbating existing educational inequalities [8], [9].

Second, teacher capacity remains a critical bottleneck. Many educators lack the digital literacy, pedagogical skills, and confidence required to integrate technology effectively into competency-based instruction. Teachers often receive minimal training in ICT use, and when training is provided, it typically focuses on basic technical skills rather than pedagogical integration. Without adequate preparation and ongoing support, teachers may use technology to replicate traditional lecture-based instruction rather than enable interactive, personalized, and skills-oriented learning [10], [11].

Third, assessment practices have not evolved to leverage ICT for formative, adaptive, or skills-based evaluation. Traditional summative assessments continue to dominate, misaligned with CBE principles. Technology offers powerful capabilities for assessment innovation, including immediate feedback, adaptive testing, learning analytics, and digital portfolios, but these capabilities remain untapped [12]. Furthermore, existing research is fragmented. Studies often focus on isolated aspects of ICT adoption without examining broader pedagogical and learning outcome implications. Theoretical frameworks such as TAM and UTAUT dominate the literature but may not adequately capture the contextual complexities of developing economies, including structural barriers, socio-economic constraints, and institutional capacity [13], [14]. The disconnect between ICT investments and educational outcomes poses significant risks for policy effectiveness and resource allocation. Without a clear understanding of how technology supports competency development, education systems may continue to invest in infrastructure without achieving intended pedagogical and learning transformations [15].

1.2 Research Objectives

i. To synthesize empirical evidence on ICT adoption trends, patterns, and challenges in Kenya, Tanzania, Rwanda, and Uganda.
ii. To evaluate the adequacy of existing theoretical frameworks in explaining ICT integration in developing economy contexts.
iii. To assess the extent to which ICT integration supports competency-based pedagogical practices and learning outcomes.
iv. To identify critical barriers to effective ICT-CBE integration.
v. To propose a comprehensive research and policy agenda for aligning ICT investments with competency-based education goals.

II. LITERATURE REVIEW

2.1 Theoretical Review

ICT in education comprises a constellation of hardware, connectivity, software, and digital content that support teaching, learning, assessment, and administration, enabling access to diverse resources, interactive and collaborative learning, flexible study arrangements, and data-informed instruction[16]. At a conceptual level, ICT is argued to transform pedagogy by shifting teachers from knowledge transmitters to learning facilitators, empowering learners to exercise greater control over their learning pathways, and supporting personalized instruction, authentic assessment, and the development of 21st-century skills such as digital and information literacy, collaboration, and creativity 16. Competency-Based Education (CBE), in turn, emphasizes mastery of clearly defined, measurable learning outcomes organized into cognitive, practical, and behavioural competency domains, with flexible progression based on demonstrated mastery and criterion-referenced, formative assessment aligned to workforce and societal needs [17, 18]. Theoretically, integrating ICT and CBE promises several advantages: adaptive systems that tailor content and pacing to individual learners, real-time feedback and learning analytics for formative assessment, digital portfolios and simulations for competency demonstration, and expanded access to high-quality resources and collaborative learning opportunities across contexts [19, 20]. Realizing this potential, however, requires alignment between technology affordances and competency frameworks, deliberate pedagogical design, and supportive institutional and policy environments rather than mere technology availability[16,19,20].

2.2 Empirical Review

Empirical evidence from East Africa shows that ICT tools are increasingly present in education systems, yet their use for competency-based pedagogy is uneven and often limited to basic functions such as content access and presentation rather than deeper transformation of teaching and learning [16, 19]. Studies report that ICT can enhance student engagement, collaboration, and access to diverse materials, but the extent to which these affordances translate into measurable competency gains depends heavily on teacher capacity, infrastructure quality, and the availability of contextually relevant digital content [16, 17, 18]. Research further indicates that while CBE reforms foreground clear learning outcomes and mastery-based progression, assessment practices remain dominated by traditional summative examinations, with limited use of ICT-enabled formative or authentic assessments that could more directly support competency tracking and feedback [17, 18, 19]. Overall, the empirical literature highlights a persistent gap between the theoretical promise of ICT-CBE integration and classroom realities, underscoring the need for outcome-oriented investigations that examine how specific ICT uses contribute to competency development in diverse East African contexts [19, 20].

2.3 Theoretical Frameworks for ICT Adoption

Several theoretical models have been applied to understand ICT adoption in educational contexts, each offering distinct perspectives on the factors influencing technology acceptance and use. The Technology Acceptance Model (TAM), developed by Davis in 1989, posits that perceived usefulness (the degree to which a person believes that using a particular system would enhance their performance) and perceived ease of use (the degree to which a person believes that using a particular system would be free of effort) are primary determinants of technology acceptance and usage behaviour. TAM has been widely applied in educational contexts to predict teacher and student adoption of digital tools, with numerous studies confirming that when educators perceive technology as useful and easy to use, they are more likely to integrate it into their practice. However, TAM has been criticized for its narrow focus on individual perceptions and its limited attention to contextual factors such as organizational support, resource availability, and social influences [21].

The Unified Theory of Acceptance and Use of Technology (UTAUT), proposed by Venkatesh et al. in 2003, extends TAM by incorporating additional constructs that capture a broader range of factors influencing technology adoption. UTAUT identifies four key determinants: performance expectancy (similar to perceived usefulness), effort

expectancy (similar to perceived ease of use), social influence (the degree to which individuals perceive that important others believe they should use the technology), and facilitating conditions (the degree to which individuals believe that organizational and technical infrastructure exists to support technology use). UTAUT also incorporates moderating variables including gender, age, experience, and voluntariness of use. The model has been widely used to examine ICT adoption in developing economies, highlighting the importance of infrastructure, institutional support, and social norms in shaping technology use. Studies applying UTAUT in East African contexts have found that facilitating conditions, including availability of devices, internet connectivity, and technical support, are particularly critical determinants of adoption [13].

The Technological Pedagogical Content Knowledge (TPACK) framework, developed by Mishra and Koehler in 2006, emphasizes the intersection of three knowledge domains: technological knowledge (understanding of digital tools and their capabilities), pedagogical knowledge (understanding of teaching and learning processes), and content knowledge (understanding of subject matter). TPACK posits that effective technology integration requires teachers to develop integrated knowledge at the intersections of these domains, including technological pedagogical knowledge (how technology can support specific pedagogical strategies), technological content knowledge (how technology can represent and transform subject matter), and pedagogical content knowledge (how to teach specific content effectively). The framework provides a lens for understanding teacher competencies required for effective ICT integration, focusing on how technology can enhance subject-specific pedagogy. TPACK has been used to design teacher professional development programs and to assess teacher readiness for technology integration [22].

While these frameworks offer valuable insights into ICT adoption, they have important limitations when applied to developing economy contexts. TAM and UTAUT focus primarily on user acceptance and individual-level factors, potentially underestimating structural barriers such as infrastructure deficits, resource constraints, policy incoherence, and institutional capacity. These models assume that technology is available and that adoption is primarily a matter of individual choice, assumptions that may not hold in contexts where access is limited and uneven. TPACK emphasizes teacher knowledge but does not fully address systemic challenges such as curriculum alignment, assessment practices, professional development systems, or school leadership. The framework focuses on what teachers need to know but provides limited guidance on how to develop this knowledge or how to create enabling conditions for its application. A more comprehensive framework is needed to capture the multi-level, context-specific factors influencing ICT-CBE integration in East Africa, including macro-level factors (national policies, infrastructure investments, curriculum frameworks), meso-level factors (institutional capacity, school leadership, professional development systems), and micro-level factors (teacher beliefs, pedagogical practices, student engagement) [23], [24].

2.4 ICT Adoption Trends in East Africa

East African countries have made significant strides in ICT infrastructure development and policy formulation over the past decade, positioning technology as a central pillar of education reform. However, implementation has been uneven, and the translation of infrastructure investments into pedagogical transformation remains incomplete.

Kenya's Digital Literacy Programme (DLP), launched in 2016, represents one of the most ambitious ICT in education initiatives in Sub-Saharan Africa. The program aimed to provide laptops and digital content to all primary schools, with the goal of equipping every Standard One learner with a digital device. The initiative was accompanied by teacher training programs and the development of digital content aligned with the national curriculum. While the DLP increased device availability significantly, implementation challenges including inadequate teacher training, limited connectivity, insufficient technical support, and lack of sustainable funding undermined its impact. Studies indicate that many devices remain underutilized, with teachers lacking the skills and confidence to integrate them effectively into instruction. Furthermore, rural schools face greater challenges in accessing connectivity and technical support, exacerbating existing inequalities [25], [26].

Tanzania's Education Sector Development Plan emphasizes ICT integration as a strategy to improve learning outcomes and teacher effectiveness. Initiatives such as the Tanzania Education and Skills for Transformation (BEST) Programme and partnerships with organizations like the African Virtual University have expanded access to digital resources and online learning platforms. The government has invested in broadband infrastructure, established ICT resource centres, and developed digital content for various subjects. However, rural-urban disparities in infrastructure and teacher capacity remain significant. Studies from Tanzania highlight persistent challenges including unreliable electricity, limited internet bandwidth, insufficient devices, and weak institutional capacity at the school level. Teacher professional development programs have been implemented, but they often focus on basic ICT skills rather than pedagogical integration, leaving educators unprepared to use technology for competency-based instruction [27], [28].

Rwanda's Smart Classroom Initiative and One Laptop Per Child program have positioned the country as a regional leader in educational technology. The government has made substantial investments in broadband infrastructure, including fibre optic networks and 4G coverage, creating a strong connectivity foundation. The Smart Classroom Initiative equips schools with computers, projectors, and internet access, while the One Laptop Per Child program provides devices to primary school students. Teacher training programs have been implemented to build capacity in ICT

use. Despite these investments, challenges in pedagogical transformation and outcome measurement persist. Studies indicate that while access to technology has improved, its use often remains limited to basic functions such as content delivery and internet browsing, with limited integration into interactive, learner-centered instruction. Assessment of the initiative's impact on learning outcomes has been limited, making it difficult to evaluate its effectiveness [29].

Uganda's ICT in Education Policy, adopted in 2008 and revised in subsequent years, promotes technology use for teaching, learning, and administration. The policy envisions ICT as a tool for improving access, quality, and relevance of education. Despite policy commitments, implementation has been hampered by limited funding, infrastructure gaps, and weak institutional capacity. Studies indicate that while access to devices has improved in urban and well-resourced schools, rural and underserved areas continue to face significant challenges. Teacher capacity remains a critical constraint, with many educators lacking training in ICT use and pedagogical integration. Furthermore, the absence of robust monitoring and evaluation systems limits the ability to assess progress and inform policy adjustments [30], [31].

2.5 Teacher Capacity and Professional Development

Teacher capacity is consistently identified as one of the most critical determinants of effective ICT integration in education. Across East Africa, studies reveal significant gaps in digital literacy, pedagogical skills, and confidence among educators, limiting their ability to leverage technology for competency-based instruction. Many teachers lack basic ICT skills, including the ability to operate computers, navigate software applications, use internet resources, and troubleshoot technical problems. Beyond technical skills, teachers often lack pedagogical knowledge for integrating technology effectively, including how to design technology-enhanced learning activities, facilitate collaborative digital work, use technology for formative assessment, and adapt instruction based on digital learning data. These capacity gaps are particularly pronounced among older teachers, those in rural schools, and those who did not receive ICT training in their pre-service education [10], [11].

Professional development programs, where they exist, often focus on basic ICT skills rather than pedagogical integration. Training typically covers how to use specific software applications or devices but provides limited guidance on how to integrate technology into subject-specific instruction or how to use technology to support competency-based learning. The result is that teachers may acquire technical skills but remain unprepared to transform their pedagogical practices. Furthermore, professional development is often delivered through one-time workshops rather than sustained, practice-oriented programs that provide ongoing support and opportunities for reflection and refinement. The absence of follow-up support, peer collaboration, and coaching limits the transfer of learning from training contexts to classroom practice [32], [33].

The TPACK framework highlights the need for integrated knowledge of technology, pedagogy, and content. Effective ICT integration requires teachers to understand not only how to use technology (technological knowledge) and how to teach (pedagogical knowledge) but also how technology can enhance the teaching of specific content (technological pedagogical content knowledge). For example, a mathematics teacher needs to understand how dynamic geometry software can help students visualize and explore geometric relationships, how to design activities that leverage this capability, and how to facilitate student inquiry using the tool. Developing this integrated knowledge requires professional development that is subject-specific, practice-oriented, and sustained over time. However, few teacher education programs in East Africa systematically develop TPACK competencies. Pre-service programs often treat technology, pedagogy, and content as separate domains, and in-service training rarely provides the sustained, contextualized support needed to develop integrated knowledge [22], [34].

Teacher beliefs and attitudes also play a critical role in ICT integration. Teachers who view technology as a valuable tool for enhancing learning, who are confident in their ability to use it, and who believe in learner-centered pedagogy are more likely to integrate ICT effectively. Conversely, teachers who perceive technology as a distraction, who lack confidence in their technical skills, or who prefer traditional teacher-centered instruction are less likely to adopt technology or may use it in ways that reinforce rather than transform existing practices. Addressing teacher beliefs requires professional development that not only builds skills but also provides opportunities for teachers to experience technology-enhanced learning, reflect on their practices, and develop a vision for how technology can support their goals [10], [11].

2.6 Infrastructure and Access Challenges

Infrastructure remains a fundamental barrier to ICT integration across East Africa. Unreliable electricity supply is the most basic yet critical challenge. Many schools, particularly in rural areas, lack consistent access to electricity, making it impossible to charge devices or maintain internet connectivity equipment. Even in schools with electricity connections, frequent power outages disrupt technology use and damage equipment [8], [9]. Limited internet connectivity represents another critical challenge. While mobile network coverage has expanded significantly, internet speeds remain slow, costs are high relative to income levels, and coverage is uneven, particularly in rural areas. Many schools lack internet connections entirely, limiting access to online resources and cloud-based learning platforms. Even

in schools with internet access, bandwidth is often insufficient to support multiple users simultaneously. The excessive cost of data is a significant barrier for both schools and individual learners [8], [9].

Insufficient hardware is a third major challenge. While device distribution programs have increased availability in some contexts, many schools still lack adequate computers, tablets, or other devices. Device-to-student ratios are often high, requiring students to share devices. Furthermore, devices are often outdated, slow, or incompatible with current software. The absence of technical support and maintenance systems means that broken devices often remain out of service for extended periods [8], [9].

Mobile technologies offer potential solutions to some infrastructure challenges. The proliferation of smartphones and mobile internet has expanded access to digital resources, enabling mobile learning initiatives. However, mobile learning faces its own challenges, including small screen sizes, limited data affordability, the need for mobile-optimized content, and concerns about distraction. While mobile learning holds promise, it must be implemented thoughtfully [35], [36]. Equity concerns are paramount. Urban schools and wealthier communities have better access to electricity, internet connectivity, and devices, while rural and low-income communities face significant barriers. This digital divide exacerbates existing educational inequalities. Policies must address these disparities through targeted investments, subsidies, community-based solutions, and strategies to ensure infrastructure development reaches underserved areas [37].

2.7 Pedagogical Practices and Learning Outcomes

The impact of ICT on pedagogical practices and learning outcomes in East Africa is mixed and context dependent. Some studies report positive effects, including increased student engagement, improved access to diverse resources, enhanced collaboration among learners, and greater motivation to learn. Technology can make learning more interactive and visually engaging, provide access to content that would otherwise be unavailable, facilitate communication and collaboration among students, and enable learners to work at their own pace. However, these benefits are often contingent on multiple factors, including teacher capacity to facilitate technology-enhanced learning, quality of infrastructure and technical support, availability of appropriate digital content, and alignment between technology use and curriculum goals [38], [39].

Few studies rigorously evaluate how ICT supports competency development or enhances specific learning outcomes. Most research focuses on access and usage patterns, documenting how often technology is used, for what purposes, and by whom, rather than examining impact on student achievement, skill acquisition, or competency demonstration. The lack of outcome-oriented research makes it difficult to assess the effectiveness of ICT-CBE integration and to identify which approaches, technologies, or implementation strategies are most effective. Studies that do examine outcomes often rely on self-reported data or teacher perceptions rather than objective measures of student learning. Rigorous evaluations using experimental or quasi-experimental designs, standardized assessments, or authentic performance tasks are rare. This evidence gap limits the ability to make evidence-based policy decisions and to justify continued investments in ICT [6], [7].

Pedagogical transformation is essential for ICT to enhance learning, yet many teachers continue to use technology to support traditional lecture-based instruction rather than learner-centered, competency-based approaches. Technology may be used to display content on a projector, to have students type rather than handwrite assignments, or to search for information online, but these uses do not fundamentally change the nature of teaching and learning. Transformative use of ICT requires teachers to shift from content delivery to facilitation, to design activities that promote critical thinking and problem-solving, to use technology for formative assessment and personalized learning, and to create opportunities for collaboration and authentic application of knowledge. Without this pedagogical shift, ICT may simply digitize traditional practices without enhancing learning. Research indicates that pedagogical transformation is challenging and requires sustained support, including professional development, access to exemplars and models, opportunities for experimentation and reflection, and a supportive institutional culture that values innovation and risk-taking [40].

The relationship between ICT usage and learning outcomes is mediated by multiple factors. The quality of digital content matters significantly; poorly designed or culturally inappropriate content may be ineffective or even counterproductive. The nature of technology use matters; passive consumption of content is less likely to enhance learning than active engagement in problem-solving, creation, or collaboration. The alignment between technology use and learning goals matters; technology should be used purposefully to support specific competencies rather than for its own sake. The broader learning environment matters: technology is most effective when embedded in a supportive context that includes clear learning goals, effective pedagogy, formative assessment, and a culture of grand expectations. Understanding these mediating factors is essential for designing effective ICT-CBE integration strategies [38], [39].

2.8 Assessment and Evaluation Practices

Assessment is a critical component of competency-based education, yet ICT-enabled assessment practices remain underdeveloped in East Africa. Traditional summative assessments dominate, with limited use of formative,

adaptive, or skills-based evaluation. Examinations typically emphasize recall and reproduction rather than application, analysis, or creation. Technology offers opportunities for assessment innovation, including real-time feedback that guides learning, learning analytics that identify patterns and predict outcomes, adaptive testing that adjusts difficulty based on performance, and digital portfolios that document competency development over time. However, these capabilities are rarely leveraged in East African contexts [12].

Digital assessment tools can support CBE by providing immediate feedback, identifying learning gaps, and enabling personalized instruction. However, implementing such systems requires technical infrastructure, teacher training in assessment design and interpretation, and alignment with curriculum standards and competency frameworks. The absence of robust digital assessment frameworks limits the ability to measure and support competency development effectively. Furthermore, concerns about academic integrity, equity in access to technology for assessment, and the validity of digital assessments require careful attention [41].

2.9 Policy and Institutional Context

Policy coherence and institutional capacity are essential for effective ICT-CBE integration. East African countries have developed national ICT in education policies, but implementation often suffers from inadequate funding, weak coordination across ministries and agencies, and limited accountability mechanisms. Policies must be accompanied by clear implementation strategies, adequate resource allocation, monitoring and evaluation systems, and mechanisms for stakeholder engagement. The gap between policy aspirations and implementation realities reflects broader challenges in education governance, including limited administrative capacity, competing priorities, and resource constraints [42].

Institutional capacity at the school and district levels is critical for effective implementation. School leaders must champion ICT integration, provide technical and pedagogical support, allocate resources strategically, and create a culture of innovation and continuous improvement. District and national education authorities must ensure equitable resource distribution, support professional development, facilitate knowledge sharing and collaboration, and use data to inform policy adjustments. Strengthening institutional capacity requires investments in leadership development, management systems, and organizational structures that support innovation [43].

III. METHODOLOGY

3.1 Search Strategy and Data Sources

This review employed a systematic approach to identify, evaluate, and synthesize empirical evidence on ICT adoption and competency-based education in East Africa. The search focused on peer-reviewed journal articles, conference proceedings, and institutional reports published between 2018 and 2025. Databases searched included Google Scholar, ERIC, Scopus, and Web of Science. Search terms combined ICT-related keywords with CBE-related terms and geographic identifiers for Kenya, Tanzania, Rwanda, Uganda, and East Africa.

3.2 Inclusion and Exclusion Criteria

Studies were included if they focused on ICT adoption, integration, or impact in primary, secondary, or tertiary education in Kenya, Tanzania, Rwanda, or Uganda; addressed pedagogical practices, learning outcomes, teacher capacity, or implementation challenges; and were published in English. Studies were excluded if they focused solely on administrative uses of ICT, lacked empirical data, or did not address the East African context.

3.3 Data Extraction and Analysis

A total of thirty-seven studies met the inclusion criteria. Data extraction focused on study context, research design, theoretical frameworks, key findings, and implications for ICT-CBE integration. Thematic analysis was used to identify patterns, trends, and gaps across studies. Findings were synthesized to address the research objectives and inform recommendations.

IV. FINDINGS & DISCUSSION

4.1 Findings

4.1.1 ICT Adoption Trends, Patterns, and Challenges (Objective 1)

The literature is dominated by studies examining technology acceptance and adoption using TAM or UTAUT frameworks. These studies consistently find that perceived usefulness, ease of use, and facilitating conditions influence ICT adoption among teachers and students. Across Kenya, Tanzania, Rwanda, and Uganda, national ICT in education initiatives have significantly expanded device availability and internet penetration over the past decade. Rwanda emerges as a regional leader, with substantial broadband infrastructure investments and structured device distribution programs, while Uganda and Tanzania continue to face implementation gaps driven by funding limitations and weak institutional capacity. Despite measurable gains in access, adoption patterns remain uneven across rural and urban settings, and technology use is predominantly limited to basic functions such as content display and internet browsing rather than transformative pedagogical application.

4.1.2 Adequacy of Existing Theoretical Frameworks (Objective 2)

TAM and UTAUT dominate the theoretical landscape, collectively accounting for most frameworks applied in reviewed studies. While these models reliably predict user acceptance, they focus primarily on individual-level perceptions and largely overlook structural barriers such as infrastructure deficits, institutional capacity gaps, and policy incoherence that are endemic to developing economy contexts. The TPACK framework provides a valuable lens for understanding teacher competency requirements but does not adequately address systemic challenges such as curriculum alignment, school leadership, and professional development ecosystems. None of the dominant frameworks adequately captures the multi-level, context-specific dynamics of ICT-CBE integration in East Africa, revealing a significant theoretical gap at macro, meso, and micro levels.

4.1.3 ICT Support for Competency-Based Pedagogical Practices and Learning Outcomes (Objective 3)

Few studies rigorously evaluate how ICT supports competency development or enhances specific learning outcomes. Most research focuses on access, usage patterns, or teacher perceptions rather than student achievement, skill acquisition, or competency demonstration. Studies that do examine outcomes report mixed results, with positive effects on student engagement, motivation, and resource access largely contingent on teacher capacity, infrastructure quality, and instructional design. Pedagogical transformation remains limited many teachers continue to use technology to replicate traditional lecture-based instruction rather than enabling learner-centered, competency-oriented approaches. Assessment practices have similarly failed to evolve, with traditional summative examinations continuing to dominate and ICT-enabled formative, adaptive, and portfolio-based assessments remaining largely untapped.

4.1.4 Critical Barriers to Effective ICT-CBE Integration (Objective 4)

Four interconnected barriers emerge consistently across the reviewed literature. First, infrastructure deficits including unreliable electricity, limited internet connectivity, and insufficient hardware constrain technology use, particularly in rural and underserved schools. Second, teacher capacity gaps in digital literacy, pedagogical integration skills, and TPACK competencies prevent effective technology use for competency-based instruction. Third, professional development programs are inadequate, typically delivering one-time, skills-focused workshops rather than sustained, practice-oriented, pedagogically integrated training. Fourth, assessment systems remain misaligned with CBE principles, with limited institutional capacity or infrastructure to support digital, formative, or competency-mapped evaluation. These barriers interact and compound one another, making isolated interventions insufficient for systemic change.

4.1.5 Research and Policy Gaps (Objective 5)

The review identifies a critical evidence gap: while investments in ICT infrastructure and CBE policy reform have accelerated, outcome-oriented research that rigorously links ICT use to competency development is scarce. Existing studies are methodologically fragmented, predominantly cross-sectional, reliant on self-reported data, and geographically skewed toward urban and well-resourced settings. Policy coherence is also lacking national ICT in education policies exist across all four countries but suffer from inadequate funding, weak inter-ministerial coordination, and limited monitoring and evaluation mechanisms.

4.2 Discussion

4.2.1 Adoption Without Transformation - A Persistent Paradox

The finding that ICT adoption has expanded while pedagogical transformation has stagnated reflects the broader pattern in East Africa, where investments have increased device availability and connectivity, but classroom practice remains largely traditional [6, 7, 25,31]. This is consistent with TAM- and UTAUT-based studies in the region, which show that perceived usefulness, ease of use, and facilitating conditions drive initial adoption but pay limited attention

to changes in pedagogy or learning outcomes 13, 21. In line with critiques of these models as adoption-stage frameworks, the reviewed evidence indicates that the presence and basic use of ICT rarely translate into competency-oriented, learner-centred instruction without deeper shifts in teacher practice and assessment [6, 7, 38,40]. These findings suggest that ICT-education research in developing economies should move beyond adoption as the primary construct and focus on integration depth, that is, the extent to which ICT is used to support CBE-aligned pedagogies, formative assessment, and demonstrable competency gains [4, 5, 19, 20].

4.2.2 Theoretical Inadequacy in Developing Economy Contexts

The reviewed literature reveals a recurring tension between the assumptions embedded in dominant ICT adoption models and the structural realities of East African education systems[6,8] TAM and UTAUT typically assume that technology is reliably available and that adoption is largely a matter of individual volition, an assumption that breaks down in contexts characterized by unstable electricity, high connectivity costs, and uneven access to devices[8]. Similarly, while TPACK illuminates the integrated technological, pedagogical, and content knowledge required for effective ICT use, it pays less attention to the policy coherence, curriculum alignment, leadership, and professional development systems that shape teachers' opportunities to enact this knowledge in practice [22]. The pattern of findings across Kenya, Tanzania, Rwanda, and Uganda therefore supports calls for contextually grounded, multi-level frameworks that simultaneously incorporate macro-level factors (national ICT and CBE policies, infrastructure investments), meso-level factors (institutional capacity, school leadership, professional development structures), and micro-level factors (teacher beliefs, classroom practices, student engagement) [43]

4.2.3 Teacher Capacity as the Central Mediating Variable

Across the literature, teacher capacity consistently emerges as the critical mediating link between ICT availability and learning outcomes in CBE contexts[10]. Studies show that many teachers possess limited digital literacy and are unfamiliar with designing technology-enhanced, learner-centred activities, particularly in rural and under-resourced schools [10, 11, 32, 33]. This aligns with TPACK's emphasis on integrated technological, pedagogical, and content knowledge, indicating that effective ICT use requires not only tool operation but also the ability to align technology with subject matter and competency-based learning goals [22 , 34[. However, existing professional development initiatives often prioritise basic technical training over sustained, subject-specific, and practice-oriented support, leaving teachers underprepared to design competency-mapped, formative, and adaptive learning experiences. The resulting capacity gaps are therefore better understood as a systemic failure of professional development policy and institutional support structures, rather than simply individual teacher deficits, with important implications for the design and scaling of teacher learning programmes.

4.2.4 Infrastructure as a Threshold Condition, not a Moderating Variable

The consistent identification of unreliable electricity, limited internet bandwidth, and inadequate hardware as key barriers across all four countries underscores that infrastructure functions as a threshold condition for ICT-CBE integration rather than a marginal moderating factor [8, 9, 25]. Studies in both urban and rural schools highlight that when electricity supply is unstable, connectivity is intermittent or unaffordable, and devices are scarce or non-functional, teachers cannot sustain meaningful technology use regardless of their motivation or skills. This challenges the treatment of facilitating conditions in TAM and UTAUT as variables that merely influence the strength of adoption intentions and instead positions basic infrastructure as a non-negotiable precondition for any substantive ICT integration in classrooms[13,21]. The evidence therefore suggests that investments in teacher training, digital content, and curriculum reform will have limited impact unless minimum infrastructure standards reliable power, adequate connectivity, and functional devices are first achieved and equitably maintained, particularly in rural and low-income settings [8, 9, 25, 35].

4.2.5 The Assessment Gap - A Missing Link in ICT-CBE Integration

The literature points to assessment as the weakest and least developed dimension of ICT-CBE integration in East Africa, despite CBE's heavy reliance on ongoing, competency-focused evaluation [6, 18, 41]. While technology has been used to support content delivery and, to a lesser extent, collaborative learning, there is little evidence of widespread adoption of ICT-enabled formative, adaptive, or performance-based assessments aligned with competency frameworks [38 , 40] . Traditional, summative, recall-oriented examinations continue to dominate, creating a misalignment between CBE policy aspirations and classroom assessment practice[17]. This pattern mirrors broader findings that assessment reform often lags other components of educational technology initiatives, resulting in situations where ICT supports learning processes but not the systematic measurement or certification of competencies [12, 39, 40]. The reviewed evidence therefore underscores the need for policy and research agendas that treat digital assessment

infrastructure, tools, and teacher assessment literacy as integral components of ICT-CBE strategies rather than peripheral add-ons [12, 17, 18, 38,41]

V. CONCLUSION & RECOMMENDATIONS

5.1 Conclusion

This review set out to examine the relationship between ICT adoption and competency-based education outcomes in East Africa, drawing on systematic analysis of thirty-seven peer-reviewed studies from Kenya, Tanzania, Rwanda, and Uganda. The evidence presents a sobering yet instructive picture: while the region has made measurable progress in expanding ICT infrastructure, device availability, and policy commitment to both ICT and CBE reform, a critical disconnect persists between technology availability and meaningful educational transformation. The dominant theoretical frameworks guiding the field TAM, UTAUT, and TPACK have provided valuable but partial explanations for this disconnect. TAM and UTAUT illuminate the individual and organizational drivers of technology acceptance but fall short in capturing the structural, institutional, and contextual barriers that characterize developing economy education systems. TPACK advances understanding of teacher competency requirements but does not address the systemic conditions policy coherence, school leadership, assessment reform, and professional development ecosystems that determine whether teacher knowledge translates into classroom transformation. Collectively, these frameworks reveal a field theoretically equipped to explain adoption but insufficiently equipped to explain integration depth, pedagogical quality, or competency outcomes.

Four cross-cutting barriers emerge as the most significant constraints on effective ICT-CBE integration: persistent infrastructure deficits, critical teacher capacity gaps, underdeveloped assessment practices, and weak policy coherence and institutional capacity. These barriers are not independent they interact and reinforce one another in ways that make isolated, single-variable interventions unlikely to produce systemic change. Addressing them requires coordinated, multi-level strategies that simultaneously strengthen foundational infrastructure, build sustained teacher competency, reform assessment systems, and align policy frameworks with implementation realities. The study contributes to the literature by synthesizing fragmented evidence across four national contexts, identifying the theoretical limitations of dominant frameworks for developing economy applications, and proposing a forward-looking research and policy agenda. The central argument advanced is that ICT's transformative potential in CBE contexts will remain unrealized until the field shifts its focus from technology access and adoption to pedagogical integration quality, competency outcome measurement, and the enabling conditions that make both possible.

5.2 Recommendations

Governments across East Africa must reorient their ICT in education strategies from infrastructure deployment as an end goal toward infrastructure as a foundation for pedagogical transformation. This requires sustained and prioritized investment in reliable electricity supply, affordable broadband connectivity, and adequate device-to-student ratios particularly in rural and underserved schools where infrastructure deficits are most acute and educational inequalities most pronounced. Beyond physical infrastructure, policy frameworks must achieve greater coherence by aligning national ICT in education policies with CBE curriculum frameworks, ensuring that technology investments are purposefully directed toward the competency outcomes that education systems are designed to produce. Inter-ministerial coordination between ministries of education, ICT, and finance must be strengthened, accompanied by dedicated funding streams, realistic implementation timelines, and robust monitoring and evaluation mechanisms capable of tracking not only access metrics but pedagogical and learning outcome indicators. Policies should also establish minimum standards for school-level ICT integration that include provisions for technical support, maintenance systems, and digital assessment infrastructure, recognizing that devices without support ecosystems rapidly become liabilities rather than assets.

School leaders play a pivotal role in determining whether national ICT policies translate into classroom-level transformation and this role demands deliberate investment. Principals and head teachers must move beyond administrative technology use to actively champion pedagogical innovation, creating institutional cultures that reward experimentation, support peer learning, and normalize reflective practice around technology integration. Resource allocation decisions at the school level should prioritize sustained professional development over one-time device procurement, recognizing that teacher capacity is the most critical determinant of whether technology enhances learning. Schools should establish communities of practice that enable teachers to share technology-enhanced lesson designs, observe each other's classrooms, and collectively solve implementation challenges. Furthermore, school leaders should work with district authorities to develop school-level ICT integration plans that are aligned with competency frameworks, include measurable targets, and are reviewed regularly to reflect emerging evidence and changing institutional conditions.

The design and delivery of teacher professional development must undergo fundamental reform if ICT is to meaningfully support competency-based instruction. Professional development programs must move beyond one-time,

skills-focused workshops toward sustained, practice-oriented, and subject-specific training models that develop integrated TPACK competencies over time. Training should be embedded in teachers' daily professional contexts, providing opportunities to design technology-enhanced lessons, implement them with learners, receive structured feedback, and refine their practice iteratively. Pre-service teacher education programs must systematically integrate TPACK development across methodology courses rather than treating technology as a standalone subject, ensuring that graduating teachers enter schools with both the technical skills and the pedagogical frameworks needed for competency-based technology integration. Attention must also be given to teacher beliefs and attitudes professional development should create space for teachers to experience technology-enhanced learning themselves, develop a personal vision for its value, and build confidence through supported experimentation rather than prescriptive compliance.

The most urgent research priority is to shift from adoption-focused studies to outcome-oriented investigations that rigorously examine how specific ICT integration approaches contribute to competency development and learning outcomes. This requires moving beyond cross-sectional survey designs reliant on self-reported data toward longitudinal studies, quasi-experimental designs, and mixed methods approaches that combine quantitative outcome measurement with qualitative investigation of implementation processes and contextual factors. Researchers should develop and validate contextually appropriate theoretical frameworks that operate at macro, meso, and micro levels simultaneously, capturing the multi-level dynamics of ICT-CBE integration in resource-constrained environments rather than applying models designed for high-income, high-infrastructure contexts. Comparative multi-site studies across the four East African countries would be particularly valuable in identifying which implementation strategies, contextual conditions, and policy configurations are most conducive to effective ICT-CBE integration. Finally, the field urgently needs investment in digital assessment research developing, piloting, and evaluating ICT-enabled formative, adaptive, and competency-mapped assessment tools that are affordable, contextually appropriate, and aligned with CBE frameworks.

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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