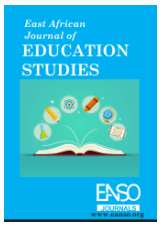

East African Journal of Education Studies
eajes.eanso.org
Volume 8, Issue 2, 2025
Print ISSN: 2707-3939 | Online ISSN: 2707-3947
Title DOI: https://doi.org/10.37284/2707-3947

EAST AFRICAN NATURE & SCIENCE ORGANIZATION

Original Article

Transforming Mathematics Education through Digital Literacy: Integrating Competency-Based Approaches in Kenyan Universities

Dr. Kipkosgei Andrew Kibet, PhD[1]

[1] University of Kabianga, P. O. Box 2030-20200, Kericho, Kenya.
[*] Author for Correspondence Email: akipkosgei@kabianga.ac.ke

Article DOI: https://doi.org/10.37284/eajes.8.2.3183

Date Published:

20 June 2025

Keywords:

Digital Literacy, Competency-Based Curriculum, Mathematics Education, Higher Education, Teacher Training, Performance-Based Assessment, TPACK, Kenya.

ABSTRACT

This study investigates how digital literacy is integrated into the Competency-Based Curriculum (CBC) framework for Mathematics Education in universities. Anchored in the Technological Pedagogical Content Knowledge (TPACK) framework, the study employs a qualitative systematic literature review to synthesize evidence from global, regional, and local contexts. It identifies five key challenges: uneven CBC implementation in Mathematics instruction, fragmented use of digital tools, teacher capacity deficits, inadequate infrastructure, and outdated assessment practices. The study further explores how these gaps undermine CBC's goals of promoting real-world problem-solving and 21st-century competencies. In response, it proposes a context-sensitive framework emphasizing teacher professional development, strategic infrastructure investment, performance-based digital assessments, and stakeholder collaboration. While the study offers actionable insights for aligning Mathematics pedagogy with CBC goals in a digital age, it acknowledges its primary limitation the reliance on secondary data through qualitative synthesis which may not fully capture evolving classroom realities.

APA CITATION

Kibet, K. A. (2025). Transforming Mathematics Education through Digital Literacy: Integrating Competency-Based Approaches in Kenyan Universities. *East African Journal of Education Studies*, *8*(2), 780-795. https://doi.org/10.37284/eajes.8.2.3183

CHICAGO CITATION

Kibet, Kipkosgei Andrew. 2025. "Transforming Mathematics Education through Digital Literacy: Integrating Competency-Based Approaches in Kenyan Universities". *East African Journal of Education Studies* 8 (2), 780-795. https://doi.org/10.37284/eajes.8.2.3183

HARVARD CITATION

Kibet, K. A. (2025) "Transforming Mathematics Education through Digital Literacy: Integrating Competency-Based Approaches in Kenyan Universities", *East African Journal of Education Studies*, 8(2), pp. 780-795. doi: 10.37284/eajes.8.2.3183

IEEE CITATION

K. A. Kibet "Transforming Mathematics Education through Digital Literacy: Integrating Competency-Based Approaches in Kenyan Universities" *EAJES*, vol. 8, no. 2, pp. 780-795, Jun. 2025.

Article DOI: https://doi.org/10.37284/eajes.8.2.3183

MLA CITATION

Kibet, Kipkosgei Andrew. "Transforming Mathematics Education through Digital Literacy: Integrating Competency-Based Approaches in Kenyan Universities". *East African Journal of Education Studies*, Vol. 8, no. 2, Jun. 2025, pp. 780-795, doi:10.37284/eajes.8.2.3183

INTRODUCTION

The evolution of digital technologies and the emergence of knowledge economies have catalysed a global revaluation of educational priorities. Mathematics, a discipline once centred primarily on abstract reasoning, is now increasingly regarded as a conduit for cultivating adaptive problem-solvers capable of navigating complex, technology-infused environments. In response, many education systems are transitioning from content-heavy, examination-driven models to competency-based education (CBE), which emphasizes demonstrable skill acquisition and lifelong learning competencies (Van Laar et al., 2017). Central to this shift is the recognition that digital literacy defined not only as the ability to use digital tools but also to think critically, solve problems, and communicate within digital ecosystems is indispensable for 21st-century mathematical learning.

Globally, digital literacy integration in Mathematics education has enabled students to visualize and manipulate mathematical objects using dynamic software like GeoGebra, Demos, and MATLAB. These tools allow for real-time graph plotting, interactive geometry modelling, and data-driven simulations, making abstract concepts more accessible and engaging. As such, digital literacy is no longer a supplementary skill but a transformative enabler of deeper mathematical understanding, creativity, and collaborative learning.

Regionally, countries in Sub-Saharan Africa have embraced competency-based reforms to align education with socio-economic transformation agendas. However, efforts to embed digital literacy within STEM disciplines, including Mathematics, have encountered significant headwinds. In Nigeria and South Africa, for instance, studies report persistent gaps in teacher digital competence, infrastructural disparities between urban and rural institutions, and minimal support for technology-enhanced pedagogy (Olaniran & Babalola, 2020; Mtsweni, 2021). These systemic challenges underscore the need for context-sensitive strategies to advance digital integration in higher education.

Kenya's adoption of the Competency-Based Curriculum (CBC) in 2017 was a bold attempt to transform educational delivery across all levels. The CBC framework articulates seven core competencies, among them critical thinking, collaboration, creativity, and digital literacy (Kenya Institute of Curriculum Development, 2017). Mathematics is a key enabler of these competencies, particularly in fostering logical reasoning, data interpretation, and analytical precision. Yet, in the country's universities, the infusion of digital literacy into Mathematics instruction remains limited and inconsistent. Many educators continue to operate within traditional pedagogical paradigms, with minimal access to digital tools like GeoGebra or online collaborative platforms, inadequate training in technology-enhanced teaching, and little institutional backing for innovation (Ogembo, 2021; Wawire & Kiru, 2021).

Problem Statement

In an ideal learning environment, integrating digital literacy into Mathematics instruction under Kenya's Competency-Based Curriculum (CBC) should enable students to visualize abstract mathematical concepts, interact with simulations, and solve applied problems using tools such as GeoGebra, Microsoft Excel, or virtual whiteboards. This integration is especially critical in university settings, where learners are expected to synthesize disciplinary knowledge with real-world technological applications (Lans et al., 2014). Digital tools, when properly embedded, enhance conceptual understanding, support data-driven problem-solving, and facilitate collaborative,

Article DOI: https://doi.org/10.37284/eajes.8.2.3183

technology-mediated learning experiences that are vital for 21st-century workforce readiness.

However, the current implementation landscape in Kenyan universities presents a stark contrast. According to the Ministry of Education (Republic of Kenya, 2016), over 60% of public universities lack sufficient ICT infrastructure to support digital teaching and learning across all faculties. Specifically, more than 70% of Mathematics departments report limited access to subject-specific digital tools such as dynamic geometry software, data visualization platforms, or mathematical simulation apps. Furthermore, a national teacher training audit by the Teachers Service Commission revealed that only 38% of university Mathematics instructors have received any form of formal digital pedagogy training tailored to CBC implementation (Ogembo, 2021). As a result, many educators lack the digital fluency required to deliver content through interactive platforms or to facilitate experiential, data-driven learning environments—relying instead on traditional, teacher-centred methods that are misaligned with CBC philosophy (Wawire & Kiru, 2021).

These structural and pedagogical challenges not only hinder the actualization of CBC goals but also exacerbate disparities in student engagement and learning outcomes across institutions, particularly between urban and rural campuses (Makokha & Mutisya, 2016). Without intentional strategies to build educator capacity and institutional infrastructure, universities risk producing Mathematics graduates ill-equipped for the digital economy.

Despite growing scholarly attention on CBC implementation in primary and secondary education, there remains a significant empirical void concerning how digital literacy is being integrated into Mathematics instruction at the university level in Kenya. Most existing studies offer broad institutional analyses without unpacking subject-specific pedagogical obstacles or evaluating the digital tools most effective for Mathematics learning (Ogembo, 2021; Wawire & Kiru, 2021). This study responds directly to that gap. By focusing specifically on Mathematics education in universities, it seeks to generate targeted insights into the barriers and enablers of digital literacy integration. Furthermore, it aims to propose context-sensitive strategies grounded in both theory and practice that institutions can adopt to align Mathematics pedagogy with CBC outcomes and 21st-century demands. In doing so, the study not only contributes to academic discourse but also offers practical value to policymakers, educators, and curriculum developers striving to future-proof Kenya's higher education system.

Research Objective

This study aims to examine the extent and nature of digital literacy integration in Mathematics instruction under Kenya's competency-based curriculum within universities. Specifically, it investigates existing challenges, highlights emerging opportunities, and proposes evidence-informed strategies for enhancing digital integration to better align Mathematics education with CBC outcomes and 21st-century skill demands.

LITERATURE REVIEW

Theoretical Framework

Technological Pedagogical Content Knowledge (TPACK) Framework

This study is informed by the Technological Pedagogical Content Knowledge (TPACK) framework, developed by Mishra and Koehler (2006), which emphasizes the intersection of three core knowledge domains: content, pedagogy, and technology. In Mathematics education, TPACK provides a useful lens for understanding how teachers can effectively integrate digital tools with pedagogical strategies to enhance conceptual understanding. The framework posits that effective teaching with technology requires a deep understanding of how technology relates not only to

Article DOI: https://doi.org/10.37284/eajes.8.2.3183

content but also to teaching methods. This theory is especially relevant to CBC implementation in Mathematics, where both the subject matter and the instructional approach must evolve to accommodate 21st-century digital competencies.

Empirical Review

Competency-Based Curriculum and Mathematics

Globally, CBC reforms have aimed to enhance mathematical thinking through learner-centered methodologies. Mulder (2014) notes that flexible CBC models in Europe improved student engagement and understanding of Mathematics by emphasizing active learning and problem-solving. Similarly, Voogt and Roblin (2012) advocate for integrating 21st-century competencies such as reasoning, collaboration, and creativity into core mathematical instruction. In the U.S., Pellegrino and Hilton (2012) found that the alignment of Mathematics standards with competency-based models facilitated deep conceptual learning and real-life application.

In sub-Saharan Africa, systemic implementation issues have affected Mathematics under CBC. Mtsweni (2021) found that in South Africa, teacher resistance and outdated assessment practices hindered Mathematics curriculum reform. In Nigeria, Olaniran and Babalola (2020) reported that Mathematics teachers lacked both pedagogical and content knowledge necessary for effective CBC delivery. Lillie and Bertram (2020) emphasized the disconnection between national education policies and classroom practices in several African countries.

Kenyan studies reinforce this pattern. Wawire and Kiru (2021) found that CBC supports logical reasoning and creativity in Mathematics but highlighted widespread implementation inconsistencies due to vague guidelines. The Kenya Institute of Curriculum Development (2017) also emphasized problem-solving and real-life application in Mathematics instruction, yet the translation of these ideas into classroom practice remains limited.

While there is global consensus on CBC's potential to transform Mathematics education, regional and Kenyan findings consistently point to practical challenges in implementation. These include curriculum misalignment, resource gaps, and insufficient training. This study aims to fill the gap by providing a context-specific analysis of CBC application in university Mathematics education.

Digital Literacy in Mathematics Education

International literature confirms the value of digital literacy in enhancing mathematical understanding. Ng (2012) demonstrated that simulations and visualizations in Australian universities significantly improved comprehension of abstract concepts. Voogt et al. (2015) found that integrating technology with inquiry-based learning enhanced student engagement and problem-solving. Cukurova et al. (2018) highlighted the role of learning analytics in personalizing instruction and fostering meaningful digital integration.

Regionally, challenges persist. Olaniran and Babalola (2020) report that despite e-learning frameworks, most Nigerian Mathematics lecturers do not incorporate digital tools due to a lack of training. Mtsweni (2021) found that South African educators often rely on traditional instruction due to digital insecurity and limited institutional support. In East Africa, Mtebe and Raisamo (2014) showed that even with substantial ICT investments, digital pedagogical skills remain underdeveloped.

In Kenya, Makokha and Mutisya (2016) observed that although e-learning platforms exist, Mathematics departments rarely use them effectively due to low digital confidence. Ogembo (2021) further noted that despite policy support, Mathematics instructors continue to use conventional methods, with minimal integration of software like GeoGebra or online collaboration tools.

Article DOI: https://doi.org/10.37284/eajes.8.2.3183

Global evidence affirms the benefits of digital literacy in Mathematics, but regional and Kenyan contexts reveal significant integration challenges. In particular, the digital competence of instructors and access to subject-specific resources are consistently lacking. This study addresses these concerns by proposing structured professional development and digital literacy benchmarks tailored to Mathematics under CBC.

Assessment and Evaluation in Mathematics

Globally, assessment reforms emphasize authentic, performance-based approaches. Voogt and Roblin (2012) argued for integrating 21st-century skills into assessment frameworks. The European Commission (2017) promotes digital portfolios and simulations for Mathematics evaluation. Ribble (2015) advocates for ethical and rigorous digital assessment practices. Darling-Hammond and Adamson (2014) support project-based learning assessments to promote critical thinking.

In Sub-Saharan Africa, Olaniran and Babalola (2020) highlighted the persistence of summative tests that contradict CBC aims. Mtsweni (2021) found limited use of formative assessments in South Africa. Mtebe and Raisamo (2014) reported a lack of capacity for digital assessments in Tanzanian universities.

Kenyan studies echo similar concerns. Wawire and Kiru (2021) observed that Mathematics assessments remain traditional and exam-centric. Ogembo (2021) reported that performance-based assessments are rare due to limited training and infrastructure.

Across all levels, there is consensus on the value of performance-based, technology-driven assessments. However, implementation gaps are prevalent in Africa and Kenya. This study seeks to analyse the feasibility and practicality of modern assessment strategies in Kenyan Mathematics instruction under CBC.

Table 1: Digital Literacy Integration in Mathematics Education Across Countries

Country/Region	Strengths in Integration	Key Challenges
Australia	Use of simulations, strong ICT in curriculum	Access inequality in remote areas
Netherlands	Inquiry-based learning with tech-rich classrooms	High teacher digital fluency needed
Nigeria	E-learning policies in place	Poor training, tech resistance among instructors
South Africa	Pilot CBC reforms in STEM	Traditional assessment dominance
Tanzania	Investments in ICT infrastructure	Lack of digital pedagogy training
Kenya	CBC includes digital literacy as a core goal	Low tech uptake, insufficient Maths-specific tools

Research Gaps

This study bridges the empirical and contextual gaps by focusing explicitly on the intersection of digital literacy and Mathematics under CBC in Kenyan higher education institutions. It applies the TPACK framework to understand how Mathematics educators integrate digital tools, evaluates the alignment between assessment practices and CBC outcomes, and proposes grounded, context-sensitive strategies to enhance pedagogy, training, and institutional readiness. In particular, the study addresses challenges related to teacher digital competence and infrastructural support, thereby offering practical pathways to improve Mathematics instruction through digital literacy under the CBC framework.

Article DOI: https://doi.org/10.37284/eajes.8.2.3183

METHODOLOGY

This study employed a qualitative, systematic literature review approach to examine the integration of digital literacy within the Competency-Based Curriculum (CBC) in Mathematics education in Kenyan universities. The qualitative approach was chosen to allow for a nuanced understanding of complex educational phenomena through in-depth thematic analysis and contextual interpretation. This design provided a structured way to analyse experiential and pedagogical data that are often embedded in diverse educational contexts and not easily quantifiable.

Research Design

A qualitative systematic review methodology was adopted to explore published studies, policy documents, and institutional reports related to digital literacy, CBC, and Mathematics education. This design is particularly suited to identifying thematic trends, implementation challenges, and theoretical perspectives while providing evidence-based insights for educational reform.

Data Sources

The review drew from both peer-reviewed scholarly literature and policy documents published between 2010 and 2024, ensuring relevance to the 21st-century education context. Sources were identified through systematic searches across databases such as ERIC, Google Scholar, JSTOR, Scopus, and African Journals Online (AJOL) using keywords including “digital literacy”, “competency-based curriculum”, “Mathematics education”, “higher education in Kenya”, and “21st-century skills”.

Document Scope and Coverage

In total, 29 documents were reviewed, comprising:

- 20 peer-reviewed journal articles covering global, regional, and Kenyan practices in CBC and digital literacy.
- Government and institutional policy frameworks, including Kenya’s Basic Education Curriculum Framework and the Digital Literacy Programme.
- Empirical studies specifically focused on Mathematics instruction and teacher readiness.

The review included both international and local sources to enable cross-contextual comparisons. Inclusion criteria were: relevance to CBC or digital literacy in education, focus on Mathematics or STEM education, and availability in English. Excluded were opinion pieces, duplicate studies, and articles lacking methodological transparency. To mitigate bias in literature selection, inclusion criteria were established to ensure relevance, methodological rigour, and diversity of perspectives. Excluded materials included non-empirical opinion pieces, duplicated records, and studies lacking clear methodology.

Data Analysis

Data was analysed using thematic analysis (Braun & Clarke, 2006), guided by the research objectives. Themes were developed deductively based on predefined areas (CBC in Mathematics, digital literacy integration, teacher preparedness, infrastructure, and assessment), and refined inductively to reflect emerging insights. Emphasis was placed on identifying patterns, contradictions, and gaps within and across global, regional, and local studies.

Presentation of Findings

Findings are presented in synthesized narratives supported by thematic matrices and summary tables. A visual model, the CBC-Digital Literacy Integration Framework, has also been developed to illustrate the interconnection between curriculum goals, digital competencies, and Mathematics pedagogy. This methodology ensured an evidence-informed, multi-level analysis of the current landscape, allowing the study to highlight gaps in

Article DOI: https://doi.org/10.37284/eajes.8.2.3183

policy, pedagogy, and infrastructure while proposing actionable recommendations to enhance Mathematics instruction in Kenya's CBC era.

RESULTS

CBC Implementation and Mathematics Education

Findings reveal that while CBC adoption in Kenyan universities has been formalized, its practical application in Mathematics instruction remains weak. For example, the Kenya Institute of Curriculum Development (2017) outlines competencies like logical reasoning and problem-solving in Mathematics, yet studies such as Wawire and Kiru (2021) highlight that implementation lacks coherence due to vague curricular guidelines. Internationally, Voogt and Roblin (2012) found that embedding 21st-century competencies in Mathematics enhances learner engagement and real-world application. Pellegrino and Hilton (2012) similarly observed that aligning national core standards with competency targets promoted deeper understanding.

Regionally, Mtsweni (2021) noted that South African universities have made progress in CBC Mathematics through incremental policy alignment and structured training. However, Olaniran and Babalola (2020) reported in Nigeria that despite national CBC aspirations, Mathematics instructors were underprepared, and implementation was fragmented.

These results indicate that successful CBC implementation in Mathematics hinges on structured policy support and professional training. Kenya's lack of Mathematics-specific pedagogical models under CBC creates inconsistencies that undermine competency development. Thus, this study addresses the research objective by exposing implementation weaknesses that hamper the alignment between curriculum intent and classroom practice.

Digital Literacy in Mathematics Instruction

Globally, digital tools like GeoGebra, Desmos, and graphing calculators are used to enhance conceptual understanding and promote inquiry-based learning (Voogt et al., 2015). In digitally advanced settings, flipped classrooms and simulations help students visualize abstract mathematical ideas. Cukurova et al. (2018) further emphasized the role of learning analytics in customizing instruction to learner needs.

In Africa, institutions face significant challenges. Olaniran and Babalola (2020) reported that Nigerian Mathematics lecturers rarely use digital tools due to a lack of skills and institutional incentives. Mtsweni (2021) found similar trends in South Africa, where e-learning remains underutilized in Mathematics despite increasing ICT infrastructure.

Kenyan universities have piloted digital Mathematics labs and virtual tutorials, but such initiatives are isolated and underfunded (Makokha & Mutisya, 2016). Ogembo (2021) noted that most Mathematics educators default to traditional methods, undermining CBC goals of digital fluency. These findings align with the research objective by identifying systemic barriers, particularly in digital infrastructure and pedagogy that prevent effective digital integration.

Teacher Preparedness and Professional Development

Globally, effective CBC integration correlates with sustained teacher development. Countries like Japan and Estonia have invested in continuous professional development to equip teachers with pedagogical and digital competencies. In Africa, Mtsweni (2021) documented that South African STEM teachers benefited from structured bootcamps, leading to improved CBC delivery. However, Olaniran and Babalola (2020) emphasized that in Nigeria, a lack of digital pedagogical skills limits CBC efficacy.

Article DOI: https://doi.org/10.37284/eajes.8.2.3183

In Kenya, Ogembo (2021) found that Mathematics educators often lack both CBC training and digital fluency. Despite national training initiatives, many teachers report insufficient time, content relevance, and follow-up. These limitations were echoed by Wawire and Kiru (2021), who noted widespread confusion over CBC expectations in Mathematics. The findings support the study's objective by confirming that teacher preparedness is a foundational challenge in digital-CBC integration. Prioritizing Mathematics-specific professional development is essential to close the gap between curriculum intent and instructional reality.

Infrastructure and Digital Access

Globally, robust infrastructure underpins successful digital instruction. Countries like Finland have universal access to high-speed internet and digital tools, which support CBC-aligned Mathematics education. In Sub-Saharan Africa, most institutions lack consistent digital access. Lillie and Bertram (2020) noted disparities in connectivity and hardware distribution in Southern Africa. Mtsweni (2021) highlighted partnerships with NGOs as partial solutions.

In Kenya, the Republic of Kenya (2016) reported that only 38% of universities met minimum ICT standards for digital instruction. Makokha and Mutisya (2016) found that poor internet access and lack of software hinder online learning. These deficits are mostly in rural institutions. These findings reaffirm the importance of strategic infrastructure investment. The review's thematic depth and systematic selection of empirical studies lend credibility to the argument that digital equity must precede CBC's success in Mathematics.

Assessment Practices in CBC Mathematics Instruction

The literature reveals a disconnect between CBC principles and the assessment practices employed in Mathematics education across many Kenyan higher education institutions. While CBC emphasizes performance-based evaluation and continuous assessment of applied competencies, most institutions still rely heavily on traditional summative assessments such as written exams and standardized tests (NCTM, 2000).

Globally, countries like the USA and Finland have embraced digital and project-based assessments, leveraging simulations, online quizzes, and e-portfolios to track learner progress in real-time (Darling-Hammond & Adamson, 2014). However, regionally, particularly in Sub-Saharan Africa, assessment innovation in Mathematics lags due to a combination of policy inertia, technological barriers, and faculty reluctance to abandon exam-centric cultures (Lillie & Bertram, 2020).

In Kenya, although national CBC policy documents advocate for formative and authentic assessment, adoption remains inconsistent and often symbolic. The lack of digital tools, poorly defined rubrics, and limited training on alternative assessments has undermined the alignment of assessment with competency goals (Ogembo, 2021). Furthermore, few platforms exist for capturing and reflecting on student growth through digital portfolios, peer assessment, or collaborative problem-solving tasks. This study addresses the research objective by examining how assessment practices deviate from CBC principles and proposing strategies to align evaluation methods with competency expectations.

Article DOI: https://doi.org/10.37284/eajes.8.2.3183

Table 2: Summary of Key Findings: Integration of Digital Literacy in CBC Mathematics Education

Thematic Area	Key Findings	Supporting Sources
CBC Implementation and Mathematics	CBC promotes deeper conceptual understanding, application of skills, and learner-centred strategies in mathematics. However, implementation is uneven across institutions.	KICD (2017); Wawire & Kiru (2021); Makokha & Mutisya (2016)
Digital Literacy in Mathematics Instruction	Digital tools enhance visualization, engagement, and conceptual exploration in mathematics. However, integration is fragmented due to inadequate pedagogical alignment.	Van Laar et al. (2017); Wulan et al. (2022); Hoyles & Lagrange (2010)
Teacher Preparedness and Professional Development	Many lecturers lack TPACK capacity and confidence. In-service training is limited, irregular, and lacks specificity for math integration.	Ogembo (2021); Mtebe & Raisamo (2014); Lillie & Bertram (2020)
Infrastructure and Digital Access	Most institutions face challenges with digital hardware, software, and stable internet. These issues are more pronounced in rural and underfunded colleges.	Republic of Kenya (2016); Makokha & Mutisya (2016)
Assessment Practices	Current math assessments remain largely summative and paper-based. There's limited adoption of digital and performance-based assessments aligned with CBC.	Ribble (2015); Darling-Hammond & Adamson (2014); NCTM (2000)

DISCUSSION

The integration of digital literacy into CBC for Mathematics education is both timely and transformative, offering new pathways for developing learners' analytical, problem-solving, and technological competencies. However, as this review has highlighted, successful implementation is hindered by persistent systemic barriers, including inadequate infrastructure, limited teacher preparedness, and insufficient policy alignment.

CBC Implementation and Mathematics

Globally, successful CBC integration into Mathematics curricula depends on well-structured policy frameworks and institutional alignment. Countries like Finland have exemplified how CBC-aligned pedagogy fosters innovation and higher-order skills. Similarly, Singapore's education system demonstrates a high alignment between competency standards and classroom practices, supported by ongoing teacher training.

However, Kenya's CBC implementation remains largely policy-driven with limited pedagogical integration. The study findings are consistent with Wawire and Kiru (2021), who found that teachers were uncertain about how to align Mathematics instruction with CBC outcomes.

This aligns with Mtsweni (2021), whose South African study revealed similar gaps in classroom-level implementation, despite top-down curriculum reforms. On the other hand, countries like Canada have emphasized gradual rollout supported by continuous feedback loops, a contrast to Kenya's abrupt system overhaul.

The global and regional comparisons reveal that while CBC holds promise for Mathematics Education, its successful implementation is tightly linked to institutional coherence and teacher alignment. Kenya's experience underscores a pressing need for practical models that bridge policy intentions with classroom realities. This study contributes by offering contextualized solutions for

Article DOI: https://doi.org/10.37284/eajes.8.2.3183

aligning Mathematics teaching practices with CBC principles.

Digital Literacy in Mathematics Instruction

Digital literacy has the potential to radically improve Mathematics education by transforming how content is delivered and engaged with. While global examples (e.g., South Korea, Netherlands) show seamless use of simulations, dynamic geometry tools, and flipped classrooms, Kenya's fragmented adoption reflects a disconnection between vision and practice. For instance, Voogt et al. (2015) document how sustained investment in teacher digital fluency in the Netherlands has enabled the widespread use of ed-tech in Mathematics.

In contrast, Ogembo (2021) and the Republic of Kenya (2016) emphasize that digital resource allocation and skills development in Kenya remain sporadic and donor-dependent. Although Wulan et al. (2022) show that digital tools significantly enhance learner engagement in Indonesia, their study notes that the effectiveness of such tools depends on institutional support and instructional coherence, both of which are lacking in many Kenyan higher learning institutions.

The literature points to strong global evidence supporting digital literacy as a driver of Mathematics engagement and achievement. However, regional studies, including those from Kenya, expose a lack of readiness and support systems.

Teacher Preparedness and Professional Development

A major insight from the review is the pivotal role of teachers as catalysts for CBC's success. Without adequate professional development in both CBC pedagogy and digital tools, even the best frameworks will falter. Globally, initiatives in Japan and Estonia, as noted by Mulder (2014), have invested heavily in teacher development as a foundation for CBC's success.

Kenyan educators, however, report low digital self-efficacy and a lack of training in CBC-aligned assessment and instruction (Ogembo, 2021). These findings contrast with Olaniran and Babalola's (2020) Nigerian study, which demonstrates positive shifts in pedagogy following structured professional development. The implication is that similar training interventions in Kenya, if contextualized could yield comparable improvements.

Global and regional evidence consistently highlight professional development as the linchpin for integrating CBC and digital literacy. Kenya's context reveals critical training gaps, particularly in aligning Mathematics instruction with digital methodologies. This study responds by recommending structured, ongoing training pathways tailored to educator needs.

Infrastructure and Digital Access

The role of digital infrastructure cannot be overstated. Kenya's infrastructural challenges, ranging from erratic internet to inadequate hardware, mirror those of many African nations, yet contrast sharply with digitally resilient systems in parts of Europe and Asia. For example, studies in Sweden and Germany show a strong correlation between broadband access and improved STEM outcomes (Voogt & Roblin, 2012). Conversely, Makokha and Mutisya (2016) highlight the uneven distribution of ICT resources across Kenyan campuses, which impedes digital integration.

While South African institutions have made progress through blended learning models supported by public-private partnerships, Kenyan universities still lack sustainable strategies to scale such solutions. This study identifies this disparity and advocates for national-level digital infrastructure investment targeting Mathematics education.

Adequate infrastructure is a precondition for effective digital integration in CBC. The contrast between well-resourced and under-resourced

Article DOI: https://doi.org/10.37284/eajes.8.2.3183

contexts underscores the structural inequities that hinder progress. This study contributes by prioritizing infrastructure development in its recommendations, with a specific focus on Mathematics delivery in higher education.

Toward Competency-Aligned Assessment in Mathematics

Findings on assessment practices indicate a critical need for realignment with CBC values. While traditional exams continue to dominate Mathematics education, global trends clearly demonstrate that authentic, technology-enhanced assessments offer more valid measures of mathematical understanding and application (& Hilton, 2012; Ribble, 2015).

The study affirms that assessment transformation cannot occur in isolation. It must be embedded within institutional culture, supported by adequate infrastructure, digital tools, and clear performance rubrics. Countries like Singapore and the Netherlands provide instructive models where adaptive assessments and continuous feedback have replaced high-stakes final exams in some STEM programs.

Conversely, in Kenya, persistent gaps in faculty capacity and a lack of robust learning management systems make implementation difficult. Yet, local innovation is possible; some universities have piloted digital math quizzes and collaborative Google Sheets projects, indicating readiness if institutional will and training align.

Across global, regional, and local contexts, the evidence shows that while awareness of CBC-aligned assessment principles exists, execution remains fragmented. The challenge lies in shifting from traditional to transformational assessment models that reflect real-world mathematical problem-solving.

This study fills the gap by emphasizing the urgent need for digital, competency-aligned assessment in mathematics and by proposing a performance-based framework that institutions can adopt. The recommendation to develop subject-specific assessment rubrics and provide assessment training is therefore grounded in both global best practices and Kenya's institutional realities.

CONCLUSIONS

Integrating digital literacy into a Competency-Based Curriculum (CBC) for Mathematics education in higher education is both urgent and strategic. This study reaffirms that while CBC provides a robust pedagogical foundation for fostering 21st-century competencies, its success is fundamentally dependent on addressing systemic barriers, most notably teacher preparedness, infrastructure deficits, and outdated assessment systems. The evidence shows that digital literacy is not simply an add-on to Mathematics instruction; rather, it redefines how learners engage with mathematical concepts, enabling them to explore, apply, visualize, and communicate mathematical reasoning in dynamic, real-world contexts.

Globally, countries such as Finland, Singapore, and the Netherlands have successfully embedded digital literacy within CBC frameworks by investing in structured teacher capacity-building, sustained digital infrastructure, and, critically, performance-based assessment reform. In contrast, regional counterparts such as South Africa and Nigeria continue to face implementation bottlenecks, where policies promoting digital integration often clash with limited institutional capacity, underfunded ICT infrastructure, and heavy reliance on traditional, summative assessment methods. In Kenya specifically, the disconnect between CBC principles and paper-based Mathematics assessments undermines the competencies CBC aims to cultivate, including problem-solving, collaboration, and real-world application.

This study makes a unique contribution by synthesizing global best practices and local constraints to develop a practical integration framework tailored to Kenya's higher education

Article DOI: https://doi.org/10.37284/eajes.8.2.3183

landscape. Unlike previous studies that focused narrowly on digital tools or general CBC rollout, this research explicitly connects teacher capacity, infrastructure access, and assessment innovation as a triad necessary for meaningful transformation in Mathematics education. In particular, it highlights the need to shift from rote testing to technology-enhanced, performance-based assessments that measure both mathematical understanding and digital fluency.

While these recommendations offer valuable insights, it is important to recognize the feasibility constraints in low-resource settings. Variability in institutional capacity, funding limitations, and regional disparities in digital access may hinder uniform implementation. Therefore, institutions must adopt a phased, context-sensitive approach guided by local needs and resource realities.

Consequently, future research should prioritize piloting the proposed integration and assessment frameworks in diverse Kenyan university contexts to refine adaptable models of implementation. Policymakers and institutional leaders must jointly invest in professional development, equitable access to digital resources, and assessment redesign that aligns with CBC learning outcomes. Only then can Mathematics education in Kenya fully realize its potential to produce graduates equipped for the complexities of a digital, data-driven global economy.

Recommendations

To effectively integrate digital literacy into CBC Mathematics education in Kenyan higher learning institutions, the following prioritized, practical, and evidence-based recommendations are proposed:

- **Prioritize Teacher Training and Capacity Building:** Establish ongoing, tiered professional development programs tailored to Mathematics educators. These should cover CBC pedagogy, digital tool proficiency (e.g., GeoGebra, Desmos), and instructional strategies for blended learning. Peer mentorship and communities of practice can further reinforce knowledge exchange and sustained capacity development.
- **Develop a Structured Digital Literacy Framework for Mathematics**: Institutions should create subject-specific digital literacy benchmarks outlining essential competencies across learning levels. This framework should align with national CBC goals and include competencies such as computational thinking, data literacy, and mathematical software proficiency.
- **Invest Strategically in Digital Infrastructure:** Allocate targeted funding toward high-impact infrastructure investments, including reliable internet, interactive whiteboards, cloud-based collaboration platforms, and subject-specific digital tools. Prioritize support for marginalized institutions to bridge the digital divide.
- **Implement Performance-Based and Technology-Enhanced Assessments:** Integrate authentic assessments that evaluate students' use of digital tools to solve mathematical problems. Use portfolios, simulations, and digital tasks that measure both mathematical reasoning and digital fluency. Establish rubrics aligned with CBC learning outcomes.
- **Promote Collaborative, Digitally Mediated Learning Environments:** Redesign classroom practices to include group problem-solving through digital platforms. Encourage tools like virtual math labs, collaborative whiteboards, and video-based explanations to enhance student engagement and peer learning.
- **Engage Key Stakeholders in Design and Feedback:** Actively involve educators, students, ICT personnel, and policymakers in co-developing digital literacy strategies. Institutionalize stakeholder feedback loops

Article DOI: https://doi.org/10.37284/eajes.8.2.3183

through periodic reviews, surveys, and pilot programs to ensure continued relevance and responsiveness.

Prioritizing teacher training and assessment innovation offers the most immediate gains, while infrastructure development and framework standardization require sustained investment. These recommendations directly respond to the systemic gaps revealed in the findings and provide a roadmap for policymakers and institutional leaders to operationalize CBC in a digitally dynamic Mathematics learning environment. Table 3 below outlines these recommendations, prioritized by feasibility and accompanied by suggested implementation metrics.

Table 3: Prioritized Recommendations for Integrating Digital Literacy into CBC Mathematics Instruction.Priority

Recommendation	Implementation Timeline	Action Description	Key Metrics for Evaluation
Teacher Training and Capacity Building	Short-term (0–2 years)	Launch regular professional development programs focused on CBC pedagogy and digital tools like GeoGebra, Desmos, and Excel. Create peer learning communities.	% of trained Mathematics faculty; usage frequency of digital tools; teacher self-efficacy scores; student performance gains
Structured Digital Literacy Framework	Medium-term (1–3 years)	Develop subject-specific benchmarks and digital competencies aligned with CBC. Include computational thinking and mathematical software use.	Existence and adoption rate of the framework; syllabus integration rate; faculty and student awareness levels
Strategic Infrastructure Investment	Medium to Long-term (1–5 years)	Upgrade internet access, devices, interactive whiteboards, and access to mathematical software. Prioritize equity across institutions.	% of institutions meeting ICT baseline; student-device ratio; functionality audit of tools in use
Performance-Based, Tech-Enhanced Assessment	Medium-term (1–3 years)	Adopt authentic assessments such as portfolios, simulations, and projects. Develop clear rubrics aligned with CBC learning outcomes.	% of courses with non-traditional assessments; digital assessment tool usage; alignment rate with CBC rubrics
Collaborative Digital Learning Environments	Short to Medium-term (1–3 years)	Promote the use of virtual whiteboards, online group tasks, and digital discussion boards in Math courses.	Number of courses implementing collaborative digital tasks; student engagement and satisfaction surveys
Stakeholder Engagement and Feedback	Immediate and Continuous	Institutionalize participatory design processes with educators, ICT officers, students, and policymakers. Conduct regular pilot testing and reviews.	Number of feedback loops or review meetings held; incorporation of stakeholder inputs into strategy updates

Article DOI: https://doi.org/10.37284/eajes.8.2.3183

Table 4: Digital Literacy-CBC Integration Framework for Mathematics Education

Strategic Pillar	Core Actions	Expected Outcomes
Teacher Capacity Building	- Design tiered, continuous professional development programs - Include CBC-aligned digital pedagogy, tools like GeoGebra, Desmos - Promote peer mentorship and communities of practice	- Competent, confident educators - Increased integration of digital tools - Sustainable teacher-led innovation
Curriculum-Linked Competency Standards	- Develop a Mathematics-specific digital literacy framework - Define benchmarks for competencies (e.g., computational thinking, software use) aligned to CBC goals	- Clear instructional goals - Alignment of digital tools with learning outcomes - Measurable progression
Infrastructure and Equity	- Invest in high-impact infrastructure (internet, digital whiteboards, math software) - Prioritize marginalized institutions for support	- Reduced digital divide - Enabling environment for digital integration - Equitable access to resources
Digital & Performance-Based Assessments	- Adopt authentic, technology-enhanced assessments (e.g., simulations, digital portfolios) - Create rubrics aligned with CBC math outcomes	- Assessments that reflect real -world competencies - Enhanced feedback for learners
Collaborative Digital Learning Environments	- Redesign classes to include digital collaboration tools (e.g., virtual labs, collaborative whiteboards) - Foster student-student and student-content interaction	- Improved engagement and critical thinking - Development of teamwork and communication skills
Stakeholder Co-creation and Feedback	- Involve educators, students, tech experts, and policymakers in designing digital strategies - Use surveys/pilot programs for iterative improvement	- Context-responsive strategies - Stronger policy-practice alignment - Increased stakeholder ownership

REFERENCES

American Library Association. (2013). *Digital literacy definitions*. American Library Association Digital Literacy Task Force.

Belshaw, D. (2011). *What is digital literacy? A pragmatic investigation* [Doctoral dissertation, Durham University]. Durham E-Theses Online.

Boaler, J. (2016). *Mathematical mindsets: Unleashing students' potential through creative math, inspiring messages, and innovative teaching*. Jossey-Bass.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Cukurova, M., Luckin, R., & Kent, C. (2018). Impact of learning analytics in education: Challenges and opportunities. *British Journal of*

Article DOI: https://doi.org/10.37284/eajes.8.2.3183

Educational Technology, 49(4), 748–764. https://doi.org/10.1111/bjet.12639

Darling-Hammond, L., & Adamson, F. (2014). *Beyond the bubble test: How performance assessments support 21st-century learning*. John Wiley & Sons.

European Commission. (2016). *EntreComp: The entrepreneurship competence framework*. Publications Office of the European Union.

European Commission. (2017). *European framework for the digital competence of educators: DigCompEdu*. Publications Office of the European Union.

Gardner, H. (1983). *Frames of mind: The theory of multiple intelligences*. Basic Books.

Kenya Institute of Curriculum Development. (2017). *Basic education curriculum framework*. Kenya Institute of Curriculum Development.

Lans, T., Blok, V., & Wesselink, R. (2014). Learning apart and together: Towards an integrated competence framework for sustainable entrepreneurship in higher education. *Journal of Cleaner Production, 62*, 37–47. https://doi.org/10.1016/j.jclepro.2013.03.036

Lillie, N., & Bertram, C. (2020). Curriculum policy and practice in sub-Saharan Africa: Balancing technical solutions and teacher agency. *Compare: A Journal of Comparative and International Education, 50*(7), 1001–1017. https://doi.org/10.1080/03057925.2019.1651192

Makokha, G. L., & Mutisya, D. N. (2016). Status of e-learning in public universities in Kenya. *International Review of Research in Open and Distributed Learning, 17*(3), 1–11. https://doi.org/10.19173/irrodl.v17i3.2235

Mishra, P., & Koehler, M. J. (2006). Technological Pedagogical Content Knowledge: A framework for teacher knowledge. *Teachers College Record, 108*(6), 1017–1054. https://doi.org/10.1111/j.1467-9620.2006.00684.x

Mtebe, J. S., & Raisamo, R. (2014). Investigating students' behavioural intention to adopt and use mobile learning in higher education in East Africa. *International Journal of Education and Development using ICT, 10*(3), 4–20.

Mtsweni, J. (2021). The impact of digital technology integration in CBC Mathematics education in South Africa. *African Journal of Educational Technology, 11*(2), 55–70.

National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics*. NCTM.

Ng, W. (2012). Can we teach digital natives digital literacy? *Computers & Education, 59*(3), 1065–1078. https://doi.org/10.1016/j.compedu.2012.04.016

Ogembo, J. G. (2021). Challenges facing the implementation of competency-based curriculum in Kenyan secondary schools. *International Journal of Current Aspects, 5*(3), 58–72.

Olaniran, S. O., & Babalola, J. O. (2020). An evaluation of CBC implementation in Nigerian tertiary institutions: Barriers and prospects. *International Journal of Educational Research, 9*(2), 120–135.

Pellegrino, J. W., & Hilton, M. L. (Eds.). (2012). *Education for life and work: Developing transferable knowledge and skills in the 21st century*. National Academies Press.

Republic of Kenya. (2016). *Digital literacy programme: Implementation framework*. Ministry of Education, Science and Technology.

Article DOI: https://doi.org/10.37284/eajes.8.2.3183

Ribble, M. (2015). *Digital citizenship in schools: Nine elements all students should know* (3rd ed.). International Society for Technology in Education.

Van Laar, E., van Deursen, A. J., van Dijk, J. A., & de Haan, J. (2017). The relation between 21st-century skills and digital skills: A systematic literature review. *Computers in Human Behavior, 72*, 577–588. https://doi.org/10.1016/j.chb.2017.03.010

Voogt, J., & Roblin, N. P. (2012). A comparative analysis of international frameworks for 21st-century competences: Implications for national curriculum policies. *Journal of Curriculum Studies, 44*(3), 299–321. https://doi.org/10.1080/00220272.2012.668938

Voogt, J., Fisser, P., Roblin, N. P., Tondeur, J., & van Braak, J. (2015). Technological pedagogical content knowledge—A review of the literature. *Journal of Computer Assisted Learning, 31*(3), 299–314. https://doi.org/10.1111/jcal.12074

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Harvard University Press.

Wawire, B., & Kiru, E. (2021). Implementation challenges of competency-based curriculum in Kenyan primary schools: A systematic review. *African Educational Research Journal, 9*(2), 234–248. https://doi.org/10.30918/AERJ.92.21.050

Wulan, E. R., Susilo, H., & Kuswandi, D. (2022). Digital literacy competencies among university students: A systematic review. *Educational Technology Research and Development, 70*(4), 1159–1177. https://doi.org/10.1007/s11423-021-10047-3

