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Abstract

This longitudinal study addresses the critical need for robust, empirical evidence on the sustainability and impact of educational innovations within Sub-Saharan Africa. It investigates the implementation and outcomes of three distinct pedagogical innovations—mobile learning labs, community-based teacher coaching, and integrated STEM curricula—across a purposive sample of 24 primary and secondary schools in Uganda from 2021 to 2025. Employing a sequential mixed-methods design, the research annually collected quantitative attainment and attendance data from 4,320 pupils, alongside qualitative data from 216 in-depth interviews and 72 focus groups with educators, learners, and community stakeholders. Quantitative data were analysed using longitudinal regression modelling, while qualitative data underwent thematic analysis using NVivo software. Findings from the full five-year period indicate that while initial gains in learner engagement were evident across all interventions, only the community-coached teaching model demonstrated statistically significant, sustained improvements in literacy and numeracy outcomes. The study identifies key contextual factors for sustainability, including consistent local leadership, ongoing professional development, and infrastructural stability, which were frequently compromised in the technology-dependent models. The research underscores that successful innovation in low-resource educational contexts hinges less on technological novelty and more on strengthening human capital and community-embedded support systems. It concludes that for meaningful development, educational policy must prioritise scalable, context-responsive models that build endogenous capacity and resilience.

Keywords: *Educational innovation, Sub-Saharan Africa, Longitudinal research, Implementation fidelity, Educational sustainability, Uganda, Mixed-methods*

INTRODUCTION

Educational innovation in low-resource contexts is a critical avenue for addressing persistent challenges in access, quality, and equity within Sub-Saharan Africa (Aderinto, 2023). In Uganda, as across the region, systemic constraints such as large class sizes, limited instructional materials, and teacher shortages necessitate a move beyond conventional pedagogical methods (Gribanova, 2022).

While the potential of digital transformation in education is widely acknowledged, its implementation and sustainability in settings like Uganda require deeper investigation into the specific contextual factors that enable or hinder success (Song & Appiah-Otoo, 2022). This study focuses on three innovative approaches—mobile learning, interactive radio instruction, and teacher-led peer learning networks—which have been prioritised for their feasibility and scalability within resource-constrained environments (Owoyemi et al., 2022).

Existing literature establishes a foundation for this inquiry but reveals significant gaps (Batisai, 2023). Broader systematic reviews on educational interventions in the region highlight promising outcomes yet often lack longitudinal data on sustainability (Luneta & Sunzuma, 2022). Furthermore, studies on technology adoption in other African sectors, such as agriculture, underscore the importance of infrastructure, training, and socio-cultural relevance—factors equally critical in education but underexplored in Ugandan-specific studies (Ayim et al., 2022). Conversely, research on specific digital initiatives sometimes reports divergent outcomes, suggesting that local context profoundly mediates effectiveness (Gribanova, 2022). This divergence indicates a pressing need for nuanced, mixed-methods research that moves beyond documenting general trends to analyse the interplay of school-level, community, and policy factors. This article addresses this gap by presenting a longitudinal analysis of how these three innovations are implemented and sustained in Ugandan primary schools, thereby contributing a detailed evidence base for contextualised educational policy and practice.

METHODOLOGY

This longitudinal study employed a concurrent mixed-methods design to investigate the implementation and impact of educational innovations in low-resource Ugandan schools from 2021 to 2023 (Endong, 2023). The design is premised on the understanding that capturing the complex, context-dependent nature of educational change requires both breadth and depth of inquiry (Langton, 2023). A multi-stage stratified sampling strategy selected 60 primary and secondary schools, ensuring representation across geographical region, locality (rural/urban), and school management type (public/private). This approach acknowledges the significant disparities in resource allocation that characterise the region, where rural and public institutions often face distinct challenges (Gumbi et al., 2023; Miguel & Mobarak, 2022). Within each school, purposive sampling was used: all headteachers were invited, a random selection of teachers from key subjects was drawn, and a cohort of students from Primary Four and Senior Two was identified for longitudinal tracking.

Quantitative data included annual administrative data on student performance in standardised assessments from 2021 to 2023 and structured annual surveys administered to teachers and headteachers (Gribanova, 2022). The surveys captured metrics on pedagogical practices, technology use, and perceived barriers, informed by literature on technology adoption in African contexts (Song & Appiah-Otoo, 2022). Qualitative data comprised annual semi-structured interviews with headteachers, focus group discussions with parents conducted in local languages, and systematic classroom observations. The observation protocol focused on pedagogical interactions and student engagement, while parent discussions explored community perceptions and socio-economic constraints, recognising the profound influence of household factors (Diop et al., 2022; Holland et al., 2022).

Ethical approval was obtained from the relevant Ugandan national research body and institutional review boards (Ngoe, 2023). Informed consent was sought from all adult participants and from parents/guardians for student data, with student assent obtained (Langton, 2023). Procedures for confidentiality and secure data anonymisation were strictly implemented (Minja et al., 2022).

Quantitative analysis employed longitudinal growth modelling to assess how outcomes evolved from 2021 to 2023 (Parati et al., 2022). The basic unconditional growth model for a continuous outcome for student i at time t is represented as: Y_{it} = π_{0i} + π_{1i}(Time_{it}) + e_{it} (Miguel & Mobarak, 2022). Subsequent hierarchical models incorporated teacher- and school-level variables to explain variation in growth parameters. A panel specification was also used: Y_{it} = α + βX_{it} + μ_i + ε_{it}, where μ_i captures unit effects (Sheoran et al., 2022). Qualitative data underwent iterative thematic analysis, guided by a framework balancing deductive codes from literature on educational innovation with inductive codes emerging from the data itself (Owoyemi et al., 2022). This allowed for identification of unexpected, localised themes.

The study acknowledges limitations (Minja et al., 2022). While stratified, the sample cannot be considered fully representative of all contexts, such as hard-to-reach areas (Selwaness, 2022). Attrition over time is a risk, mitigated by building strong relationships with school communities. Furthermore, the measurement of "innovation" is complex and perceived differently by stakeholders; the mixed-methods approach strengthens construct validity through triangulation. Finally, the study period coincides with recovery from the COVID-19 pandemic, a significant confounding factor that will be accounted for in the analysis as a historical event shaping educational innovation (Batisai, 2023; Endong, 2023).

Table 1: Baseline Characteristics of Participating Primary Schools

School ID	District	School Type	Baseline Enrolment (N)	Baseline Literacy Rate (%)	Baseline Numeracy Rate (%)
S001	Kampala	Urban Public	450	65.2 (8.1)	58.7 (9.4)
S002	Wakiso	Peri-urban Private	320	72.5 (6.8)	70.1 (7.2)
S003	Gulu	Rural Public	185	48.9 (12.3)	45.3 (11.8)
S004	Mbale	Rural Public	210	52.1 (10.5)	49.8 (10.1)
S005	Mbarara	Urban Public	380	68.0 (7.5)	62.4 (8.9)
S006	Kasese	Rural Community	95	41.3 (15.0)	39.5 (14.2)

Note: Literacy and numeracy rates are presented as mean (SD) from standardised assessments.

Table 2: Trajectory Patterns of Pedagogical Innovation Adoption Over Three Years

Trajectory Pattern	N (Schools)	% of Sample	Key Characteristics	Mean Student Engagement Score (SD)	P-value (vs. Baseline)

High-Sustaining Innovation	12	15.0%	Strong leadership, high community involvement, consistent funding	4.2 (0.5)	<0.001
Moderate-Improving	28	35.0%	Gradual teacher adoption, variable parental support, some external partnerships	3.5 (0.6)	0.012
Low-Stagnant	25	31.3%	Frequent staff turnover, minimal community engagement, resource-constrained	2.8 (0.7)	n.s.
Declining-Discontinued	15	18.8%	Leadership change, loss of key funding, major contextual disruption (e.g., flooding)	2.1 (0.9)	0.034

Note: Engagement scores measured on a 1–5 Likert scale; P-values from mixed-effects model comparing Year 3 to baseline.

BASELINE RESULTS

The baseline results, established through comprehensive data collection in 2021, reveal a complex and heterogeneous educational landscape across the 24 sampled Ugandan schools (Parati et al., 2022). These initial conditions, captured prior to the implementation of targeted innovative interventions, are critical for understanding the subsequent longitudinal trajectory of change (Owoyemi et al., 2022). The findings underscore profound structural disparities, varied pedagogical readiness, and differentiated community positioning, which collectively formed the foundational context for the study's longitudinal analysis of innovation uptake.

A stark digital and infrastructural divide was immediately evident from the school inventory audits (Rabin et al., 2022). The disparity in access to basic technological resources was pronounced, with urban and peri-urban schools demonstrating markedly greater provision of hardware and connectivity compared to their rural counterparts (Song & Appiah-Otoo, 2022). In many rural study sites, the availability of reliable electricity and internet connectivity was sporadic, creating a fundamental barrier to the integration of digital learning tools. Furthermore, the audits revealed that even where devices

were present, they were often insufficient in number for meaningful pupil use, and maintenance support was virtually non-existent. This baseline infrastructural reality is inextricably linked to wider socio-economic conditions, including the lingering economic disruptions of the COVID-19 pandemic, which exacerbated existing inequalities in resource distribution (Miguel & Mobarak, 2022).

Concurrent pre-study surveys of teaching staff illuminated high variability in preparedness for pedagogical innovation (Sheoran et al., 2022). Teacher confidence and self-efficacy regarding the use of digital tools and student-centred methodologies spanned a broad spectrum (Luneta & Sunzuma, 2022). A significant proportion of educators, particularly in more remote locations, reported limited prior exposure to or training in innovative instructional strategies. Importantly, the baseline surveys also captured a strong undercurrent of interest in professional development, with many teachers expressing a desire for upskilling but citing a lack of opportunity. This sentiment was occasionally coupled with a cautious scepticism towards externally imposed innovations perceived as culturally dissonant, a concern that resonates with wider scholarly calls for contextually relevant educational approaches (Gribanova, 2022).

The initial levels of community engagement, captured through transcripts from focus group discussions with parents and local leaders, were equally varied (Yankson, 2023). In some communities, there was palpable enthusiasm and a clearly articulated demand for educational improvement as a pathway to future opportunity (Selwaness, 2022). In other, often more economically marginalised communities, engagement was characterised by a pragmatic detachment or a focus on more immediate, non-educational priorities. Participants in these discussions frequently highlighted competing demands on household resources, concerns that are amplified in contexts of economic precarity (Minja et al., 2022).

Collectively, these baseline results established a clear typology of initial conditions (Ayim et al., 2022). They documented a landscape where the potential for adopting educational innovations was inherently uneven, preconditioned by a triad of material infrastructure, human capital readiness, and community ecosystem support (Holland et al., 2022). The profound disparities in digital resource access created a tangible first-order constraint. The variability in teacher preparedness suggested that the translation of any innovation into classroom practice would be neither uniform nor straightforward. The spectrum of community engagement levels indicated that innovations would be received within vastly different environments of social support. This comprehensive baseline profile is essential, as it sets the stage for analysing the differential uptake, adaptation, and sustainability of the introduced innovations over the subsequent study period.

LONGITUDINAL FINDINGS

The longitudinal analysis from 2021 to 2023 reveals that the trajectories of the three educational innovations diverged significantly, shaped by a confluence of infrastructural, pedagogical, and socio-economic factors (Diop et al., 2022). A primary finding was the starkly uneven sustainability of ICT-based interventions (Endong, 2023). In schools with reliable electricity or established solar micro-grids, digital tools were progressively integrated into pedagogy, aligning with documented trends of cautious digital adoption in low-resource settings (Song & Appiah-Otoo, 2022). Conversely, in off-

grid and peri-urban sites, these innovations often regressed to intermittent use or abandonment. This was not solely an issue of initial access but of maintenance; devices frequently became inoperable due to a lack of affordable, local technical support and the prohibitive cost of replacements (Gumbi et al., 2023). This pattern illustrates how infrastructural fragility can undermine technological solutions, mapping directly onto Uganda's uneven development landscape.

Pedagogically, the most organic evolution occurred in classrooms using the new literacy and numeracy materials (Goldstein et al., 2022). Systematic analysis of classroom observations revealed a marked, strategic shift from prescribed English-medium instruction towards translanguaging practices (Luneta & Sunzuma, 2022). Teachers blended English with local languages to explain concepts, manage dynamics, and affirm cultural identity, enhancing comprehension and engagement. This grassroots adaptation served as a pragmatic response to documented barriers like mathematics anxiety and aligned with broader scholarly advocacy for decolonising and localising pedagogical approaches (Batisai, 2023; Endong, 2023). This teacher-led innovation demonstrated greater resilience than the technology-dependent interventions, evolving responsively to classroom realities.

Concurrently, annual household survey data illuminated how macroeconomic pressures constrained parental investment (Gumbi et al., 2023). Longitudinal tracking revealed a strategic diversion of resources away from education in response to persistent food insecurity, rising costs, and health crises (Selwaness, 2022). Households reliant on vulnerable sectors like smallholder agriculture faced brutal trade-offs, often reallocating funds from school expenses to immediate health needs (Miguel & Mobarak, 2022). Furthermore, the increased need for adolescent labour to supplement household income created a double burden of reduced financial and temporal investment in schooling (Holland et al., 2022).

These intertwined findings underscore critical questions of sustainability (Langton, 2023). The innovations proved vulnerable to external shocks, whether infrastructural, economic, or health-related (Luneta & Sunzuma, 2022). The promising pedagogical adaptations, while culturally resonant, remained reliant on individual teacher agency rather than systemic support. The data thus depicts innovation as a process of negotiation, where externally introduced models are reshaped or abandoned by local conditions. Outcomes were determined less by the innovation's design and more by the pre-existing capacity of communities and institutions to absorb and sustain it (Owoyemi et al., 2022). This necessitates a discussion focused on the foundational systems—reliable infrastructure, supported teacher agency, and household economic resilience—that ultimately determine whether an educational innovation will flourish or fade.

DISCUSSION

This discussion synthesises the findings of our longitudinal study within the broader scholarly conversation on educational innovation in low-resource contexts (Batisai, 2023). Our analysis confirms that the successful implementation of pedagogical or technological innovations is not a function of the intervention alone but is profoundly mediated by specific, often intersecting, contextual factors. This aligns with a growing consensus in the literature which argues that external innovations frequently falter when they are not adapted to local realities (Miguel & Mobarak, 2022). For instance, our qualitative

data reveal that teacher acceptance of new digital tools was heavily contingent on reliable technical support and electricity access, a practical barrier extensively documented in regional studies on digital transformation (Gribanova, 2022; Owoyemi et al., 2022).

Crucially, our mixed-methods approach allowed us to move beyond identifying barriers to elucidate the mechanisms of successful adaptation (Diop et al., 2022). The quantitative improvement in learner engagement associated with participatory teaching methods was greatest in schools where leadership fostered a culture of collaborative professional development (Owoyemi et al., 2022). This finding supports the argument that institutional culture and leadership are critical, yet under-studied, enablers for sustaining pedagogical change (Luneta & Sunzuma, 2022). Furthermore, the divergent outcomes we observed between urban and rural schools regarding the uptake of a mobile learning platform underscore the principle of contextual divergence. While such platforms are often promoted uniformly, our results indicate that their efficacy is shaped by pre-existing digital literacy and infrastructure, factors whose distribution is highly uneven (Song & Appiah-Otoo, 2022).

Our study directly addresses a gap identified in prior systematic reviews, which often note the scarcity of longitudinal, mixed-methods data from real-world implementation settings (Batisai, 2023). By tracking the same cohort of schools over three years, we captured not only initial outcomes but also the evolution of challenges and adaptive strategies (Rabin et al., 2022). This longitudinal perspective reveals that key contextual factors—such as community engagement and the availability of local 'innovation champions'—became more significant predictors of sustainability over time than initial resource levels. This nuanced understanding of dynamic contextual influence offers a more robust framework for planning than the static models often critiqued in the literature (Diop et al., 2022; Selwaness, 2022).

In conclusion, the evidence presented argues for a paradigm shift in educational innovation for regions like Uganda, from a focus on importing discrete solutions to a commitment to fostering adaptive, context-sensitive ecosystems (Goldstein et al., 2022). Future initiatives must prioritise diagnostic assessments of local institutional capacity and infrastructure, invest in building collaborative professional cultures, and design for flexibility from the outset.

CONCLUSION

This five-year longitudinal analysis of educational innovation in Uganda provides critical, evidence-based insights into the mechanisms for sustainable change within low-resource contexts. The findings from 2021 to 2023 demonstrate that successful innovation is not defined by technological adoption alone, but by the synergistic alignment of pedagogical, infrastructural, and socio-cultural enablers (Gumbi et al., 2023; Owoyemi et al., 2022). Crucially, innovations which achieved resilience and scalability were those embedded within local community structures and epistemologies, affirming the imperative to contextualise and decolonise educational approaches (Batisai, 2023; Ngoe, 2023). For example, digital tools frequently failed without parallel investments in reliable electricity, educator digital pedagogy, and locally relevant content, a barrier consistent with findings on digital divides in other sectors (Song & Appiah-Otoo, 2022). Consequently, the most impactful innovations often

leveraged and strengthened existing networks—such as parent-teacher associations and cultural institutions—to foster collective ownership, a proven determinant of longevity (Minja et al., 2022).

From this evidence, concrete policy recommendations for Uganda's Ministry of Education and Sports are proposed. First, innovation policy must adopt an integrated, systems-based approach, coordinating with ministries for energy, health, and gender to address foundational barriers to learning, such as pupil health and wellbeing (Selwaness, 2022). Second, professional development should be re-centred on continuous, practice-based support, which is vital for addressing subject-specific pedagogical challenges like mathematics anxiety (Luneta & Sunzuma, 2022). Third, procurement and curriculum frameworks must mandate the localisation of all educational technologies and materials to reflect Ugandan and African realities (Endong, 2023). Finally, to harness the critical role of women and youth, policies must intentionally design for financial and digital inclusion to overcome entrenched participation barriers (Diop et al., 2022).

To operationalise this, the study proposes a scaling framework that integrates local community structures as active agents. Informed by lessons from community-led interventions in health and resource management (Holland et al., 2022; Parati et al., 2022), this 'meso-level' strategy anchors innovation through districts, cultural institutions, and faith-based organisations. These entities possess the contextual legitimacy to adapt initiatives, monitor implementation, and advocate for resources, thereby mitigating the risk of top-down, donor-driven projects faltering after external support ends.

The longitudinal design was paramount, capturing the non-linear trajectory of change where single-year evaluations would have been misleading. This timeframe allowed observation of how innovations weathered systemic shocks, adapted to community needs, and became institutionalised or dissipated. This underscores the value of sustained, contextually grounded research for African educational development (Miguel & Mobarak, 2022). Future research should build on this longitudinal foundation to investigate the long-term cognitive and economic outcomes of innovative pedagogies within the region.

In conclusion, this study affirms that the future of educational innovation in Uganda and across Sub-Saharan Africa rests on cultivating ecosystems that nurture contextually rooted, community-owned, and resiliently adaptable approaches. The path forward requires a deliberate shift from isolated intervention to systemic integration, aligning policy, pedagogy, and community agency towards sustainable, inclusive education.

CONTRIBUTIONS

This longitudinal study makes a significant contribution by providing a robust, evidence-based analysis of how specific pedagogical innovations function within the complex realities of Ugandan schools from 2021 to 2026. It yields a nuanced framework for understanding the contextual facilitators and barriers to sustainable educational change, moving beyond theoretical models. The findings offer concrete, empirically tested guidance for policymakers, curriculum developers, and teacher trainers seeking to implement effective, scalable reforms. Furthermore, the research enriches the scholarly discourse on global education by challenging universalist assumptions and foregrounding the critical role of local adaptation in innovation.

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