AJCSEE
Asian Journal of Collaboration of Social Environment and Education
AJCSEE 4(1): 17-30
ISSN 3025-2466

Institute for Advanced Science, Social and Sustainable Future
MORALITY BEFORE KNOWLEDGE

Digital transformation for learner equity: The role of artificial intelligence tutors in achieving sustainable development goal 4 in sub-Saharan Africa

Richmond Ampah-Mensah[1],* Sidney Odongo[2], Abdul Agbo Aziz[3], Diana Hardiyant[4]

[1] *Department of Informatics, Faculty of Engineering and Computer Science, Universitas Muhammadiyah Semarang, Semarang, Central Java 50273, Indonesia;*
[2] *Department of Food Technology, Faculty of Agricultural Science and Technology, Universitas Muhammadiyah Semarang, Semarang, Central Java 50273, Indonesia;*
[3] *Department of Management, Faculty of Business and Economics, Universitas Muhammadiyah Semarang, Semarang, Central Java 50273, Indonesia;*
[4] *Department of English Literature, Faculty of Education and Humanities, Universitas Muhammadiyah Semarang, Semarang, Central Java 50273, Indonesia.*
*Correspondence: amaphmensahrich@gmail.com

Received Date: February 11, 2026 Revised Date: May 25, 2026 Accepted Date: July 27, 2026

ABSTRACT

Background: Educational imbalance continues to constrain progress toward sustainable development goal 4 (SDG 4) in sub-Saharan Africa (SSA). Chronic teacher shortages, overcrowded classrooms, and high data costs exclude many marginalised learners and sustain high levels of learning poverty. High quality human tutoring can generate large learning gains of around one third of a standard deviation, consistent with a pooled effect size of 0.37, but remains financially and logistically difficult to scale in SSA. **Methods:** This article applies a comparative synthesis framework to evidence from randomised controlled trials, large scale field pilots, case studies, and policy and monitoring reports. It compares traditional human tutoring, AI supported tutoring systems, and low bandwidth mobile first interventions to assess their implications for scalability, affordability, and learner equity, and interprets the findings through economic, technological, and inclusion lenses and a decolonial perspective. **Findings:** Emerging AI tutors and mobile based platforms in Ghana, Sierra Leone, and Kenya indicate that low bandwidth, mobile first designs can approximate tutoring like gains while substantially reducing marginal cost and data usage, for example through WhatsApp and SMS delivery. These tools can serve as force multipliers for overstretched teachers and expand access to curriculum aligned support for learners in rural and low income communities. At the same time, persistent constraints related to infrastructure, teacher capacity, data governance, and risks of "AI in Education colonialism" limit who can benefit and how sustainably. **Conclusion:** AI tutors can contribute to more equitable learning in SSA when they are embedded in teacher led routines, engineered for low bandwidth environments, and governed by robust, decolonially informed frameworks that protect data and centre local curricula, languages, and communities. Their contribution depends on parallel investments in infrastructure, teacher professional development, and culturally responsive AI design. **Novelty/Originality of this article:** This study proposes a decolonially informed, low-bandwidth AI tutoring framework to promote equitable and sustainable education in underserved communities.

KEYWORDS: artificial intelligence; digital transformation; learner equity; SDGs 4; sub-Saharan Africa.

Cite This Article:
Ampah-Mensah, R., Odongo, S., Aziz , A. A., Hardiyant, D. (2026). Digital transformation for learner equity: the role of AI tutors in achieving SD4 in sub-Saharan Africa. *Asian Journal of Collaboration of Social Environment and Education, 4*(1), 17-30. https://doi.org/10.61511/ajcsee.v4i1.2026.3421

1. Introduction

Education is a basic right and a crucial tool for sustainable human development, advancing both individual capabilities and national economic growth. However, in sub-Saharan Africa (SSA), quality education remains out of reach for many learners, and large gaps persist in access, participation, and learning outcomes (Zickafoose et al., 2024). SSA continues to struggle to achieve inclusive, equitable, and quality education because of limited access and inclusion, physical and curricular barriers, and an inadequate number of teachers, combined with misaligned policies and funding priorities (Aarts et al., 2019; Odhiambo et al., 2023). Sustainable Development Goal 4 (SDG 4), Equitable and Quality Education, calls for learning environments that provide high-quality teaching and learning and expand opportunities for lifelong learning (The 17 Goals | Sustainable Development, n.d.). The global community has committed to achieving SDG 4 by 2030 through improved literacy and numeracy, vocational training, skill development, disability sensitivity, sufficient qualified teachers, and the elimination of gender disparities. In this article, learner equity is understood as the fair distribution of educational opportunities and outcomes across different groups, including girls, children with disabilities, rural learners, and youth affected by conflict, with particular attention to access, participation, and achievement (Zickafoose et al., 2024; Evans & Acosta, 2021).

To examine learner equity in a structured way, the analysis in this paper is organised around three interlocking lenses. First, an economic lens focuses on the affordability and scalability of different models, including their costs for governments, schools, and households. Second, a technological lens addresses digital access, such as connectivity, bandwidth, device availability, and data prices. Third, a facilities, infrastructure, and inclusion lens considers how school resources, geography, gender, disability, and conflict shape who is able to benefit from educational innovations (Aarts et al., 2019; Kis-Katos & Sparrow, 2019; Lembani et al., 2019). Together, these lenses provide a basis for assessing whether new approaches narrow or widen existing gaps in learner equity in SSA.

Recognising the scale of these challenges, governments and international organisations have highlighted the potential of digital technologies to reach excluded learners. UNESCO (United Nations Educational, Scientific and Cultural Organization) has identified artificial intelligence (AI) as a critical instrument for advancing SDG 4, and its policy guidance documents emphasise that AI in education should be human-centred, equity-driven, and aligned with the Education 2030 Agenda, with appropriate safeguards for data privacy and inclusion (UNESCO, 2025). Recent initiatives illustrate this interest. In Brazil, the state of Piaui has introduced AI into secondary education through a three-year programme that integrates AI literacy and ethics into classrooms, reaching students in remote public schools (UNESCO, 2025). In North Africa and the Middle East, Egypt's Mahara-Tech platform offers AI and digital skills training in Arabic, reportedly serving hundreds of thousands of users, many from marginalised or under-resourced groups (UNESCO, 2025). Complementary developments in Asia show how AI-enhanced education can be adapted to diverse contexts, including generative AI tutors for rural and migrant children in China and blended digital models such as DOORS in Pakistan and Tanzania (Cao, 2023; Chen et al., 2024).

However, many SSA learners remain far from SDG 4, of the promising examples. In 2023, the COVID-19 epidemic resulted in 250 million children and youth out of school. Marginalised populations were most affected (Chen et al., 2024). Pre-pandemic UNESCO data showed that many African nations were behind on SDG 4 in terms of access, equity and quality, while regional learning assessments showed academic stasis or decline. These trends suggest that business as usual solutions are unlikely to close SSA learning gaps within the SDG timetable.

One long-standing conclusion from education research is that tutoring can enhance achievement. Bloom's famous 2 sigma problem demonstrated that students who received individual tutoring did better than students in regular classes (Bloom, 1984). A meta-analysis of experimental studies suggested that quality tutoring can significantly improve learning outcomes, with a pooled effect size of 0.37 standard deviations for tutoring programmes (Nickow et al, 2020). In most low- and middle-income countries, where teacher shortages and large class sizes are common (Clotfelter et al, 2006; UNESCO, 2024), high costs and organizational needs have left customized human tutoring underdeveloped.

AI-powered tutoring systems are an attempt to make personal education scalable and affordable (Holmes et al., 2022). AI instructors that are mobile first and delivered via short message services or messaging applications can digitally support 85 percent of SSA residents who live in areas with mobile broadband access but don't use the internet due to high data rates. Early tests in Ghana, Sierra Leone and Kenya show that low-bandwidth AI tutors and platforms can boost learning and offer teachers additional instructional support within resource constraints. These models imply that AI instructors might leapfrog the web by delivering relevant instructional content along less data-heavy and cheaper pathways (Björkegren et al., 2024).

Fig. 1. Sub-Saharan Africa map
(South African Oil & Gas Alliance, n.d.)

Critical research has also pointed out the hazards of AI in Education colonialism. AI systems designed in and for the Global North may replicate knowledge hierarchies, marginalise local languages and epistemologies and increase dependent on external technology providers in SSA (Holmes et al., 2022). Experience of African higher education points to the significance of regional groundedness of design, participative techniques and knowledge of historical power relations when embedding AI into teaching and learning (Le Grange, 2016; Mohamed et al., 2020). A custom GPT (Generative Pre-trained Transformer) project for pre-service teachers in Ghana, trained on local course syllabi and culturally responsive frameworks, illustrates how AI tools can be better linked with local curricula and pedagogies while also avoiding some of these dangers.

This study investigates whether and when AI tutors can foster student equity in SSA. It contrasts traditional human teaching, AI-supported tutoring systems and other digital interventions using a comparative synthesis methodology using randomised controlled trials, large-scale field pilots, case studies and policy and monitoring reports. The analysis is guided by three research questions: (a) How might AI tutors be developed and used to tackle teacher shortages and educational disparities in sub-Saharan Africa? (b) What are the key infrastructural, cultural and ethical barriers to the adoption of AI-enabled educational technologies in the region? (c) What measurable learner equity outcomes (i.e. access, performance, retention) have been associated This essay aims to contribute policy-relevant insights to governments and partners who use AI tutors to achieve SDG 4 in SSA, by framing accumulating empirical findings within an explicitly equitable and decolonial lens that is attentive to the historical and social context of the region.

The education gap in sub-SaharanAfrica and the feasibility of SDG 4 has been the subject of studies. The region struggles with providing quality inclusive and equitable education due to underfunded schools, geographic distance, and social isolation (Zickafoose et al., 2024). Regional monitoring reports and evaluations demonstrate that many African countries were already off track to reach key SDG 4 metrics on access, equity and learning outcomes prior to the COVID-19 epidemic, and that the pandemic widened learning disparities. These findings mean that the achievement gap for pupils from low-income households, rural communities, conflict zones and marginalized social groups will not be closed by 2030 with business as usual tactics.

In this vein, tutoring research has demonstrated that some instructional support can enhance learning outcomes. Bloom's famous 2 sigma problem experiment showed that students tutored by a human outperformed their peers in ordinary courses, suggesting that a very customized education can increase achievement (Bloom, 1984). Nickow et al. (2020) performed a comprehensive review and meta-analysis of tutoring programs and reported a pooled impact size of 0.37 standard deviations, similar to some of the most effective remedial and focused interventions in education. There is, however, evidence from empirical studies on teacher labour markets and classroom environments that the continuing teacher shortages, huge class sizes and narrow fiscal space for extra personnel or outsourced services hinder the expansion of intense human tutoring in many low- and middle-income settings.

Research in AIED (Artificial Intelligence in Education) is thriving worldwide. The AI in education study (2010-2020) covers intelligent tutoring systems, adaptive assessment, automated feedback and learning analytics, with a growing emphasis on personalized and data-driven instruction (Zhai et al., 2021). Asian and global research shows that AI-assisted technology can help teachers design courses and assess students, particularly in remote areas and among migrant youth. Few studies have explored low bandwidth, mobile-first AI teachers for SSA connection and cost limits. Most have looked at mid to high income scenarios.

AI-mediated teaching and low-bandwidth interventions are increasing in Africa, but are understudied. We have trialled and evaluated a WhatsApp-based AI maths tutor in Ghana, M Shule in Kenya, and an AI chatbot for trainers in Sierra Leone, utilizing basic phones and limited data. Examples from Asia and Latin America illustrate how AI-enabled learning technologies may be integrated into national plans and system-level reform (Chenet al., 2024; Rivas et al., 2023).

Finally, critical scholarship discusses the implications of AI deployment for education equity, power and knowledge production. AI in education must be human-centered, equity-driven and aligned with the Education 2030 Agenda, with strong safeguards for data privacy, inclusiveness and local capacity building (UNESCO, 2025; UNESCO Chair on AI in Education, 2023). Decolonial and critical perspectives warn that the import of Global North AI systems into African education systems without contextual adaptation risks re-enforcing colonial knowledge hierarchies, marginalizing local languages and epistemologies and increasing reliance on external technology providers. African higher education studies call for participatory and locally-grounded AI design and governance because dominant AI technologies often reflect training data and pedagogical assumptions that do not fully accommodate indigenous knowledge systems or local histories. A Ghanaian pre-service teacher GPT, which draws on local syllabi and culturally relevant frameworks, is an example of how AI-based tools can better align with local curricula and address these issues.

This literature shows that tutoring is one of the most effective instructional interventions, that AI-supported tools have begun to extend personalized instruction into diverse contexts, and that SSA faces unique equity and decolonial challenges that shape how AI tutors should be used. Empirical studies, particularly randomized controlled trials and large-scale pilots in Ghana, Kenya, and Sierra Leone, estimate the learning and cost effects of low bandwidth AI tutors and related platforms, while conceptual and policy-oriented work addresses governance, ethics, and long-term system transformation. This study synthesizes this empirical information through an explicit learner equity and decolonial perspective, focusing on AI tutor models' cost, technological feasibility, and inclusiveness in sub-Saharan Africa.

2. Methods

2.1 Methods & synthesis framework

The study employed a comparative synthesis framework to explore how AI-powered tutoring systems can improve learner equity and advance SDG 4 in sub-Saharan Africa (SSA). This approach combined peer-reviewed articles, randomized controlled trials (RCTs), quasi-experimental studies, and policy reports from organizations such as UNESCO and the World Bank. It contrasted traditional face-to-face education with AI-supported tutoring and other digital tools like web searches and mobile platforms (Bloom, 1984; Nickow et al., 2020; Evans & Acosta, 2021; Björkegren et al., 2024; UNESCO, 2025). By integrating empirical learning outcome data with policy analyses, the study balanced the potential of new technologies with the region's unique socio-educational context.

2.2 Search strategy and inclusion criteria

Targeted searches were performed across academic databases like Google Scholar and ERIC, as well as grey-literature repositories, using keywords related to AI tutoring, low-bandwidth mobile learning, the digital divide, and SDG 4. The inclusion criteria focused on school-age education literature published from 2018 to 2025, while also including foundational historical context on tutoring effectiveness and structural constraints in SSA (Bloom, 1984; Nickow et al., 2020; Evans & Acosta, 2021). Selected sources included empirical assessments of AI interventions (RCTs, pilots), regional SDG 4 data, and policy reports on equity, data governance, and decolonial critiques in the Global South (Holmes et al., 2022; Decolonising AI, n.d.; Mendoza et al., 2023). Records unrelated to the focus were excluded during title and abstract screening based on outcomes like access and equity; however, exact exclusion numbers were not systematically recorded, and a PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) diagram was not included, with the strategy's limitations clearly explained instead (Haddaway et al., 2018; Siddaway et al., 2019).

2.3 Data extraction, cross-case comparison, and limitations

Data extraction employed three analytical lenses to gather empirical metrics—such as population, delivery channel, dosage, cost, and effect sizes—along with qualitative policy aspects including data governance, decolonial issues, and teachers' roles (Holmes et al., 2022; Björkegren et al., 2024; Henkel et al., 2024). The cross-case comparison involved three steps: identifying relevant documents, extracting both quantitative and qualitative indicators, and synthesizing findings across traditional schooling, AI-supported tutoring, and alternative EdTech initiatives to assess cost, scalability, and equity (Haddaway et al., 2018; Evans & Acosta, 2021). Methodological limitations included biases toward English-language sources from well-funded regions, a lack of rigorous regional AI tutor RCTs, and high intervention heterogeneity, which hindered precise impact measurements (Evans & Acosta, 2021; Henkel et al., 2024). As a result, the findings highlight patterns for future research, emphasizing the need to standardize outcome measures and investigate AI's interaction with local curricula and teacher training (Siddaway et al., 2019; UNESCO, 2025).

3. Results and Discussion

3.*1 Quantifying the main constraints for learner equity*

The baseline evidence confirmed that education systems in sub-Saharan Africa faced severe and overlapping constraints that directly affected learner equity. Large numbers of children remain out of school or fail to complete basic education. Estimates suggest that about 32 million children of primary school age are not enrolled, and many of those who are enrolled struggle to acquire foundational skills (Evans & Acosta, 2021; Rivas et al., 2023). Average student–teacher ratios in many countries far exceed UNESCO's indicative benchmark of 40 to 1, which limits teachers' ability to provide individualised support. For example, in Sierra Leone the student–teacher ratio is reported at 42 to 1, and only 19 percent of surveyed teachers hold a bachelor's degree, which constrains opportunities for pedagogical development and effective instruction (UNESCO, 2024; Björkegren et al., 2024).

From an economic and technological perspective, the digital divide remains a major barrier. Although around 85 percent of the population in SSA may be covered by mobile broadband, only a much smaller share actually uses the internet, with high data costs cited as the leading constraint on use (Björkegren et al., 2024; Lembani et al., 2019). In Ghana, for instance, 41.5 percent of schoolchildren lack internet access, which limits their ability to benefit from conventional web-based learning resources (Ghana Schoolchildren Lack ICT Access, n.d.). These patterns are compounded by socioeconomic inequalities, since children from poorer households are more likely to attend schools with limited resources and weak infrastructure (American Psychological Association, 2017; Aikens & Barbarin, 2008). Physical and institutional factors also matter. Conflict and forced displacement disrupt schooling for millions of children in the region, and public resources are often diverted away from education toward security expenditures (Kis-Katos & Sparrow, 2019). Traditional distribution channels for textbooks and learning materials are vulnerable to logistical failures and leakages, which particularly disadvantage remote and marginalised communities (Björkegren et al., 2024).

Taken together, these findings show that learners in SSA face inequities along all three analytical lenses outlined earlier. Economically, there are insufficient resources to recruit and retain enough qualified teachers and to provide high-quality remedial programmes at scale. Technologically, high data costs and limited connectivity constrain the use of conventional web-based tools. In terms of facilities, infrastructure, and inclusion, rural schools, conflict-affected areas, and learners with disabilities or other vulnerabilities continue to receive fewer and lower-quality learning opportunities. Any AI-enabled solution, including AI tutors, must therefore be assessed against this demanding baseline.

3.2 Evidence from AI tutor and low-bandwidth interventions

Within this constrained environment, a set of recent empirical studies examined AI-mediated tutoring and related low-bandwidth digital interventions in African contexts. A 17-month field study in Sierra Leone evaluated a WhatsApp-based AI chatbot designed to support teachers with lesson planning, fact-finding, and other instructional tasks (Björkegren et al., 2024). The study recruited 469 teachers who were given access to both the AI chatbot and the country's most commonly used web search engine. Usage logs and teacher ratings show that teachers turned to the AI chatbot more frequently than to web search, especially for factual queries and lesson preparation. Importantly, the AI tool was accessed via basic mobile devices and was engineered to minimise data consumption, which reduced the cost barrier for teachers in low-income settings.

Complementary evidence from Ghana focuses on Rori, an AI-powered mathematics tutor delivered via WhatsApp. In a randomised evaluation across 11 Rising Academies schools, lower-secondary students in the treatment group received one hour per week of additional math practice mediated by Rori during study hall, while both treatment and control groups continued the same face-to-face curriculum (Henkel et al., 2024). After a single term, the study reported an effect size of around 0.36 standard deviations in mathematics learning gains for the Rori group relative to controls, a magnitude comparable to many high-quality human tutoring programmes and other proven remedial interventions (Henkel et al., 2024; Nickow et al., 2020). The intervention was designed for low-bandwidth networks and basic mobile devices, indicating that AI-mediated tutoring can be implemented without one-to-one laptops or high-speed broadband.

Additional insights came from adjacent models such as M-Shule in Kenya, which combines SMS (Short Message Service) -based delivery with an AI-enhanced backend to provide personalised lessons and quizzes directly to learners' mobile phones (M-Shule, n.d.). M-Shule has engaged tens of thousands of learners and households across multiple counties and operates at a monthly cost of about 2 to 5 USD per learner. Although M-Shule is not an AI tutor in the narrow sense, it illustrates how low-tech, high-impact digital solutions can reach learners who lack internet access, especially in rural and low-income communities. Together, these cases suggest that low-bandwidth AI tutors and related platforms can generate measurable learning gains while operating within the economic and technological constraints typical of SSA.

From an equity standpoint, the available studies indicated that AI-mediated tools can expand access to structured learning opportunities and pedagogical support in contexts where human tutoring at scale is not feasible. Teachers using the Sierra Leone chatbot reported that it helped them prepare lessons more efficiently and find contextually relevant examples, which can indirectly benefit learners in overcrowded classrooms (Björkegren et al., 2024). In Ghana, the Rori trial suggests that even a relatively modest dosage of AI-mediated practice, integrated into regular school schedules, can improve mathematics outcomes for lower-secondary students, including those in schools that serve low-income communities (Henkel et al., 2024). M-Shule's low-cost SMS delivery model further shows that digital support can reach households without smartphones or broadband, which is particularly important for rural and peri-urban learners (M-Shule, n.d.).

3.3 Comparing AI tutors with conventional and other digital models

The comparative synthesis allowed a more explicit contrast between AI-supported tutoring, conventional tutoring, and other digital approaches. High-quality human tutoring was consistently associated with large effect sizes for learning but is expensive and difficult to scale. Bloom's original 2 sigma work and subsequent meta-analyses, including Nickow et al. (2020), demonstrated that individualised human tutoring can move average students well above typical classroom performance levels (Bloom, 1984; Nickow et al., 2020). However, supplying equivalent levels of one-to-one or small-group support to large cohorts of learners in SSA would require substantial numbers of additional tutors, robust supervision systems, and long-term financing, which are unlikely to be available given existing teacher shortages and fiscal constraints (Clotfelter et al., 2006; UNESCO, 2024).

By contrast, AI tutors and low-bandwidth platforms offer the possibility of approximating some of the benefits of personalised practice and feedback at much lower marginal cost. The Ghana Rori study suggests that when AI-mediated practice is carefully aligned with curricula and integrated into school routines, it can generate learning gains similar in size to those produced by many human tutoring programmes, while relying on existing mobile infrastructure rather than on new personnel (Henkel et al., 2024; Nickow et al., 2020). The Sierra Leone chatbot and M-Shule examples further show that AI-supported tools can be configured to run on basic handsets with minimal data usage, which reduces economic barriers for both schools and households (Björkegren et al., 2024; M-Shule, n.d.).

Other digital models, such as unsupervised web search, radio, or television educational broadcasting, tend to offer broad reach but limited personalisation. The Sierra Leone study directly compared commonly used web search engine with the AI chatbot for teachers' information needs. The findings indicated that web search consumed significantly more data per query and that a higher share of search results were rated as inaccurate or less helpful compared with AI chatbot responses (Björkegren et al., 2024). Table 1 summarises these differences in terms of cost, data usage, quality, and accuracy.

Table 1. Comparative cost, data usage, quality, and accuracy of web search versus AI chatbot for teacher support in Sierra Leone

Metric	Web search (google.com)	AI chatbot (WhatsApp-based)	Main finding
Cost	2.41 USD per 1,000 results loaded	0.30 USD per 1,000 responses	AI is about 87 percent less expensive
Data usage	3,107 times more data required per result	Minimal data per response	AI uses data far more efficiently
Quality	Lower ratings for relevance, helpfulness, correctness	Higher ratings for relevance, helpfulness, correctness	AI provides more relevant and helpful answers
Accuracy	31 percent of results rated inaccurate	10 percent of responses rated inaccurate	AI responses perceived as more accurate

(Björkegren et al., 2024).

From the perspective of the three analytical lenses, these comparisons suggest that AI tutors and related low-bandwidth tools occupy a middle ground. They are less resource-intensive than high-frequency human tutoring and more personalized and data-efficient than generic web search or broadcast media. For equity, this positioning is important. Under the economic lens, AI-supported models can reduce the marginal cost of additional practice and information, which is critical for low-income learners and schools. Under the technological lens, their low-bandwidth design makes them more accessible in settings where data prices are high and connectivity is unstable. Under the facilities and inclusion lens, teacher-in-the-loop designs and SMS-based delivery channels can better reach learners in rural schools and marginalized communities that have been poorly served by earlier waves of EdTech.

3.4 AI tutors as potential equity equalizers

Across the cases reviewed, a recurring theme is that AI tutors and low-bandwidth digital tools can function as equity equalizers when they are deliberately engineered for accessibility and contextual relevance. The Sierra Leone AI chatbot, which operates via WhatsApp and is tuned to local curricula, provides teachers with quick access to relevant content and lesson planning support. Teachers also use it to generate localized stories and examples in languages and cultural frames that are not well documented on the open web, thereby enriching the learning experiences of pupils who rarely see their context reflected in formal materials (Björkegren et al., 2024). In this way, the tool extends both informational and cultural access, notably for schools in rural and low-resource communities.

Similarly, the Rori tutor in Ghana demonstrates that AI-mediated practice can be delivered in a low-friction way through existing devices, which can benefit learners who would otherwise have limited exposure to targeted remedial support. Because the intervention was integrated into regular school schedules and aligned with the curriculum, it did not rely on families' ability to purchase extra tutoring or devices, which is an important consideration for equity (Henkel et al., 2024). M-Shule's SMS-based approach illustrates how an emphasis on low-cost delivery and basic handset compatibility can extend personalized learning opportunities to households that are often excluded from more data-intensive digital offerings (M-Shule, n.d.).

These examples indicate that AI tutors can support equity along several dimensions. They can increase access to structured, curriculum-aligned learning opportunities for learners who would otherwise receive little individualized attention. They can improve learning outcomes, at least in the short term, when thoughtfully integrated into classroom practice. They can also narrow aspects of the digital divide by providing useful services over channels that are more affordable and familiar than traditional web browsing or complex applications. However, these benefits are not automatic. They depend on careful design choices that priorities data efficiency, localization, and alignment with teachers' practices.

3.5 Barriers and risks for equitable implementation

Despite their promise, AI tutors face important barriers and risks that must be acknowledged in any equity-focused discussion. At the most basic level, they cannot fully overcome structural infrastructure deficits. In communities with no reliable electricity or any form of connectivity, AI-enabled tools remain out of reach, regardless of how efficient they are in data usage (Lembani et al., 2019). Unless investments in basic infrastructure are scaled up and targeted toward marginalized regions, AI tutors' risk mainly serving populations that are already better connected, which could widen digital and educational divides.

Cultural and political-economy considerations are equally important. Scholars of AI in education have warned about AIED colonialism, where tools developed in and for the Global North are exported to the Global South without sufficient adaptation, thereby reinforcing asymmetries in knowledge production and pedagogy (Holmes et al., 2022; Decolonizing AI, n.d.; Artopoulos, 2024). Studies from South Africa and other African higher-education contexts highlight that mainstream AI systems often reflect training data and assumptions that neglect local languages, histories, and epistemologies, and that this can marginalize alternative ways of knowing (Le Grange, 2016; Mohamed et al., 2020). The risk is that AI tutors might encode and reproduce these biases, especially if they are trained mostly on non-African corpora and deployed without local oversight.

There are also significant governance, ethical, and data-protection challenges. The use of AI tutors involves the collection and processing of learner data, which raises concerns about privacy, consent, and potential misuse. UNESCO and other organizations have emphasised the need for robust regulatory frameworks that define responsibilities, protect children's data, and ensure transparency and accountability in the design and deployment of AI tools in education (UNESCO, 2025; UNESCO Chair on Artificial Intelligence in Education, 2023; Antwi-Boampong et al., 2025). Without such frameworks, there is a risk that AI tutors could be adopted in ways that priorities commercial interests or narrow performance metrics over broader educational and equity goals.

Finally, the heterogeneity of contexts within SSA means that interventions that show positive results in one setting cannot be assumed to generalise straightforwardly to others. Differences in language, curriculum, governance capacity, and teacher professional development can significantly shape both implementation and outcomes. The Ghana, Sierra Leone, and Kenya cases reviewed here are informative, but they represent only a small portion of the diversity across SSA. More evidence is needed across a wider range of countries, school types, and learner groups before strong generalisations can be made.

3.6 Comparative advantages of AI-supported models

Despite these constraints, the comparative analysis suggests that AI-supported models possess certain advantages over conventional approaches in addressing teacher shortages and learning gaps at scale. Estimates of the global teacher shortfall imply that millions of additional teachers would be needed to meet universal primary and secondary education targets by 2030, with a particularly large share of this gap concentrated in SSA (UNESCO, 2024; UN News UNESCO, 2024). Meeting these needs through recruitment and training alone is unlikely, given fiscal and institutional limitations. AI tutors, in contrast, can be replicated at low marginal cost once the underlying systems and content have been developed, which makes them attractive from an economic lens.

Moreover, AI-supported models can be continually updated and adapted, which offers flexibility in responding to curricular reforms or emerging needs. When they are designed around low-bandwidth channels and integrated with teacher-led instruction, they can also reduce the "verification tax" on educators by providing concise summaries of learner progress and highlighting common misconceptions, rather than adding to teachers' workloads with complex interfaces (Björkegren et al., 2024; Holmes et al., 2022). For learners in marginalized communities, this combination of scalability, adaptability, and alignment with existing school structures can provide a more realistic path toward increased access to quality support than large-scale human tutoring alone.

3.7 Building teacher capacity and AI literacy

The evidence reviewed underscores that the effectiveness of AI tutors as tools for learner equity depends heavily on teachers. Across the cases in SSA and in comparative examples from other regions, AI-enabled interventions are most successful when they support and extend teachers' work rather than attempt to replace it (Chen et al., 2024; Education Ministers Artificial Intelligence in Schools Taskforce, 2023; Holmes et al., 2022). In Sierra Leone, the chatbot was explicitly designed as a teacher-facing tool that simplifies lesson planning and content retrieval, and teachers reported high adoption and perceived usefulness (Björkegren et al., 2024). In Ghana, the Rori trial embedded AI-mediated practice into supervised study hall sessions, which kept teachers at the centre of classroom management and instructional decisions (Henkel et al., 2024).

These patterns align with emerging guidance from UNESCO and the UNESCO Chair on AI in Education, which emphasise that professional development and AI literacy for teachers are critical for harnessing AI to support SDG 4 (UNESCO, 2025; UNESCO Chair on Artificial Intelligence in Education, 2023). Capacity-building initiatives in SSA increasingly include modules on ethical AI use, data privacy, and classroom applications, alongside communities of practice that allow educators to share experiences and strategies (Antwi-Boampong et al., 2025). When teachers are involved as co-designers and informed gatekeepers, they are better positioned to ensure that AI tutors are used in ways that are pedagogically sound, culturally relevant, and targeted toward learners who stand to benefit the most, such as girls, rural students, and those with disabilities. Overall, the results suggest that AI tutors and related low-bandwidth platforms can play a meaningful role in advancing learner equity in SSA when they are designed and governed with explicit attention to economic constraints, technological realities, and the inclusion of marginalised groups. Their contribution is likely to be greatest where they complement strong teacher professional development, locally grounded curricula, and robust public oversight, rather than functioning as stand-alone technological fixes.

4. Conclusions

The study explored the potential of AI tutors to promote learner equity and support SDG 4 in sub-Saharan Africa. The best are human tutors, but their high costs prevent scalability in places where teachers are in short supply and resources are lacking. The other side of the coin is that low-bandwidth AI tutors have proven in Ghana, Sierra Leone and Kenya that integrated platforms can improve learning outcomes at a lower cost and with less data usage. These models act as force multipliers for overburdened educators by offering opportunities for practice, feedback, and culturally relevant content to underserved rural, low-income, and marginalized communities. The success will hinge on designing these tools for low-cost channels, adapting to local pedagogies, and providing ongoing teacher training and AI literacy.

The analysis also brought up risks and limitations, including that AI tutors should not replace essential infrastructure, and that using them without modification could lead to AIED colonialism, reinforcing Western knowledge and marginalizing local languages. The limited and biased evidence base renders the findings indicative rather than conclusive. The article argues for the inclusion of the AI tutors in the national strategies from a decolonial lens through investments in infrastructure and affordable data, appropriate governance and data protection, culturally responsive and multilingual AI and the involvement of the teachers, governments, communities and learners.

Acknowledgement

The authors would like to express their sincere gratitude to all individuals and institutions who provided support and assistance throughout the preparation and completion of this article. The authors greatly appreciate the valuable contributions, guidance, suggestions, and encouragement provided by all parties involved. Their support has contributed significantly to the successful completion of this research and manuscript.

Author Contribution

Each authors contributed to the development and completion of this article.

Funding

This research received no external funding.

Ethical Review Board Statement

Not available.

Informed Consent Statement

Not available.

Data Availability Statement

Not available.

Conflicts of Interest

The authors declare no conflict of interest.

Declaration of Generative AI Use

During the preparation of this work, the authors used Perplexity AI, Grammarly, and Google Gemini to assist in finding sources related to the study, suggesting points, and also assisting in improving the grammar, clarity, and academic tone of the manuscript. After using this tool, the authors reviewed and edited the content as needed and took full responsibility for the content of the publication.

References

Aarts, H., Greijn, H., Mohamedbhai, G., & Jowi, J. O. (2020). The SDGs and African higher education. In M. Mawere & R. Mubaya (Eds.), *Africa and the sustainable development goals* (pp. 231–241). Springer. https://doi.org/10.1007/978-3-030-14857-7_22

Aikens, N. L., & Barbarin, O. (2008). Socioeconomic differences in reading trajectories: The contribution of family, neighborhood, and school contexts. *Journal of Educational Psychology, 100*(2), 235–251. https://doi.org/10.1037/0022-0663.100.2.235

Ministry of Education, Singapore. (n.d.). *Artificial intelligence in education*. https://www.moe.gov.sg/education-in-sg/educational-technology-journey/edtech-masterplan/artificial-intelligence-in-education

Artopoulos, A. (2024). *AI and unequal knowledge in the Global South*. NORRAG. https://www.norrageducation.org/ai-and-unequal-knowledge-in-the-global-south/

Björkegren, D., Choi, J. H., Budihal, D. P., Sobhani, D., Garrod, O., & Atherton, P. (2025). *Could AI leapfrog the web? Evidence from teachers in Sierra Leone*. arXiv. https://doi.org/10.48550/arXiv.2502.12397

Bloom, B. S. (1984). The 2 sigma problem: The search for methods of group instruction as effective as one-to-one tutoring. *Educational Researcher, 13*(6), 4–16. https://doi.org/10.3102/0013189X013006004

Cao, B. (2023). AI tutor: Solution for China's disadvantaged and under-resourced children. *Lecture Notes in Education Psychology and Public Media, 32*, 133–141. https://doi.org/10.54254/2753-7048/32/20230834

Chen, W., Mason, J., Badar, F. B., Mishra, S., & Rodrigo, M. M. T. (2024). Digital technology for inclusive and equitable quality education. In A. Kashihara, B. Jiang, M. M. T. Rodrigo, & J. O. Sugay (Eds.), *Proceedings of the 32nd International Conference on Computers in Education* (Vol. 1, pp. 1–4). Asia-Pacific Society for Computers in Education. https://doi.org/10.58459/icce.2024.5068

Clotfelter, C. T., Ladd, H. F., & Vigdor, J. L. (2006). Teacher-student matching and the assessment of teacher effectiveness. *Journal of Human Resources, 41*(4), 778–820. https://doi.org/10.3368/jhr.XLI.4.778

Langeveldt, D. C., & Pietersen, D. (2024). Decolonising AI: A critical approach to education and social justice. *Interdisciplinary Journal of Education Research, 6*(S1), 1–9. https://doi.org/10.38140/ijer-2024.vol6.s1.07

Education Ministers Artificial Intelligence in Schools Taskforce. (2023). *Australian framework for generative artificial intelligence in schools: Consultation paper*. Australian Government Department of Education. https://education.nsw.gov.au/content/dam/main-education/about-us/strategies-and-reports/consultation-items/AI_Consultation_Paper.pdf

Evans, D. K., & Acosta, A. M. (2021). Education in Africa: What are we learning? *Journal of African Economies, 30*(1), 13–54. https://doi.org/10.1093/jae/ejaa009

Haddaway, N. R., Macura, B., Whaley, P., & Pullin, A. S. (2018). ROSES reporting standards for systematic evidence syntheses: Pro forma, flow-diagram and descriptive summary of the plan and conduct of environmental systematic reviews and systematic maps. *Environmental Evidence, 7*, Article 7. https://doi.org/10.1186/s13750-018-0121-7

Henkel, O., Horne-Robinson, H., Kozhakhmetova, N., & Lee, A. (2024). Effective and scalable math support: Experimental evidence on the impact of an AI-math tutor in Ghana. In *Artificial intelligence in education: Posters and late breaking results, workshops and tutorials, industry and innovation tracks, practitioners, doctoral consortium and blue sky* (pp. 373–381). Springer. https://doi.org/10.1007/978-3-031-64315-6_34

Holmes, W., & Tuomi, I. (2022). State of the art and practice in AI in education. *European Journal of Education, 57*(4), 542–570. https://doi.org/10.1111/ejed.12533

Espinoza-Revollo, P., Ramirez, A., Atherton, P., & Mackintosh, A. (2022). *School leaders' preferences on school location in Sierra Leone: An individual and school-level study*. EdTech Hub. https://doi.org/10.53832/edtechhub.0106

Kis-Katos, K., & Sparrow, R. (2019). *Conflict and education in Sub-Saharan Africa* (IZA Discussion Paper No. 13069). IZA Institute of Labor Economics.

https://www.iza.org/publications/dp/13069/the-heterogeneous-effects-of-conflict-on-education-a-spatial-analysis-in-sub-Saharan-africa

Le Grange, L. (2016). Decolonising the university curriculum. *South African Journal of Higher Education, 30*(2), 1–12. https://doi.org/10.20853/30-2-709

Lembani, R., Gunter, A., Breines, M. R., & Dalu, M. T. B. (2020). The same course, different access: The digital divide between urban and rural distance education students in South Africa. *Journal of Geography in Higher Education, 44*(1), 70–84. https://doi.org/10.1080/03098265.2019.1694876

Mendoza, E. J. P., Caranto, L. C., & David, J. J. T. (2023). Role of AI in education. *International Journal of Research, Innovation and Social Science, 6*(3), 260–268.

Mohamed, S., Png, M.-T., & Isaac, W. (2020). Decolonial AI: Decolonial theory as sociotechnical foresight in artificial intelligence. *Philosophy & Technology, 33*, 659–684. https://doi.org/10.1007/s13347-020-00405-8

Morgan, P. L., Farkas, G., Hillemeier, M. M., & Maczuga, S. (2009). Risk factors for learning-related behavior problems at 24 months of age: Population-based estimates. *Journal of Abnormal Child Psychology, 37*, 401–413. https://doi.org/10.1007/s10802-008-9279-8

M-Shule. (n.d.). *M-Shule*. https://www.mshule.com/

Nickow, A. J., Oreopoulos, P., & Quan, V. (2020). *The impressive effects of tutoring on PreK-12 learning: A systematic review and meta-analysis of the experimental evidence*. EdWorkingPapers. https://doi.org/10.26300/eh0c-pc52

Nyaaba, M., & Zhai, X. (2024). *Developing custom GPTs for education: Bridging cultural and contextual divide in generative AI*. SSRN. https://doi.org/10.2139/ssrn.5074403

Odhiambo, N. M., Owusu, E. L., & Asongu, S. A. (Eds.). (2023). *Finance for sustainable development in Africa: Evolution, impact and policy implications*. Routledge. https://doi.org/10.4324/9781003215042

Reardon, S. F., Valentino, R. A., Kalogrides, D., Shores, K. A., & Greenberg, E. H. (2013). *Patterns and trends in academic achievement gaps*. Stanford University.

Rivas, A., Buchbinder, N., Barrenechea, I., González Casado, J., Soto Sira, V. G., Díaz Fouz, T., Leal Martínez, J. J., Martínez Valle, A., Limón, C., López, E., Vega, M., & Hernández Pereira, A. (2023). *The future of artificial intelligence in education in Latin America*. Fundación ProFuturo & Organisation of Ibero-American States for Education, Science and Culture. https://oei.int/wp-content/uploads/2023/04/the-future-of-artificial-intelligence-in-education-in-latin-america-oei-profuturo.pdf

Saripudin, D., & Haryani, I. (2021). The role of artificial intelligence in education. *Proceeding Seminar Nasional & Call for Papers*, 134–148.

Shaban, F. (2020). Rebuilding higher education in northern Syria. *Education and Conflict Review, 3*, 53–59. https://discovery.ucl.ac.uk/id/eprint/10109117/

Siddaway, A. P., Wood, A. M., & Hedges, L. V. (2019). How to do a systematic review: A best practice guide for conducting and reporting narrative reviews, meta-analyses, and meta-syntheses. *Annual Review of Psychology, 70*, 747–770. https://doi.org/10.1146/annurev-psych-010418-102803

South African Oil & Gas Alliance. (n.d.). *Overview of oil & gas in the sub-Saharan Africa region*. https://www.saoga.org.za/web/oil-and-gas-overview/overview-oil-gas-sub-Saharan-africa-region

United Nations. (n.d.). *The 17 goals: Sustainable development*. https://sdgs.un.org/goals

United Nations Department of Economic and Social Affairs & UNESCO Institute for Statistics. (2023). *The Sustainable Development Goals report 2023: Goal 4 extended report*. United Nations. https://unstats.un.org/sdgs/report/2023/extended-report/

United Nations News. (2024, February). *UN issues global alert over teacher shortage*. https://news.un.org/en/story/2024/02/1147067

UNESCO Chair on Artificial Intelligence in Education. (2023). *UNESCO AIED Chair website*. Beijing Normal University. https://aiedchair.bnu.edu.cn/

UNESCO Institute for Statistics. (2017). *Reducing global poverty through universal primary and secondary education* (Policy Paper 32). UNESCO.

https://uis.unesco.org/sites/default/files/documents/reducing-global-poverty-through-universal-primary-secondary-education.pdf

UNESCO. (2025). *Artificial intelligence in education*. https://www.unesco.org/en/digital-education/artificial-intelligence

World Bank. (2022). *Ending learning poverty*. https://www.worldbank.org/en/topic/education/brief/ending-learning-poverty

Zhai, X., Chu, X., Chai, C. S., Jong, M. S. Y., Istenic, A., Spector, M., Liu, J.-B., Yuan, J., & Li, Y. (2021). A review of artificial intelligence (AI) in education from 2010 to 2020. *Complexity, 2021*, Article 8812542. https://doi.org/10.1155/2021/8812542

Zickafoose, A., Ilesanmi, O., Diaz-Manrique, M., Adeyemi, A. E., Walumbe, B., Strong, R., Wingenbach, G., Rodriguez, M. T., & Dooley, K. (2024). Barriers and challenges affecting quality education (Sustainable Development Goal #4) in Sub-Saharan Africa by 2030. *Sustainability, 16*(7), 2657. https://doi.org/10.3390/su16072657

Biographies of Authors

Richmond Ampah-Mensah, Department of Informatics, Faculty of Engineering and Computer Science, Universitas Muhammadiyah Semarang, Semarang, Central Java 50273, Indonesia.

- Email: amaphmensahrich@gmail.com
- ORCID: N/A
- Web of Science ResearcherID: N/A
- Scopus Author ID: N/A
- Homepage: N/A

Sidney Odongo, Department of Food Technology, Faculty of Agricultural Science and Technology, Universitas Muhammadiyah Semarang, Semarang, Central Java 50273, Indonesia.

- Email: akumuodongo18@gmail.com
- ORCID: N/A
- Web of Science ResearcherID: N/A
- Scopus Author ID: N/A
- Homepage: N/A

Abdul Agbo Aziz, Department of Management, Faculty of Business and Economics, Universitas Muhammadiyah Semarang, Semarang, Central Java 50273, Indonesia.

- Email: abdulazizagbo@gmail.com
- ORCID: N/A
- Web of Science ResearcherID: N/A
- Scopus Author ID: N/A
- Homepage: N/A

Diana Hardiyant, Department of English Literature, Faculty of Education and Humanities, Universitas Muhammadiyah Semarang, Semarang, Central Java 50273, Indonesia.

- Email: diana@unimus.ac.id
- ORCID: N/A
- Web of Science ResearcherID: N/A
- Scopus Author ID: N/A
- Homepage: N/A