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From Adoption to Inclusion: Shifting Teachers' Mindsets Through Technology Integration and Culturally Sustainable Pedagogy in STEM Education in Sub-Saharan Africa

JULIET Ibukunoluwa BABAWUMI
Olufunke Temitope Afolabi
Opeyemi Comfort Jesubunmi, university of ibadan
Mr. Viyon Dansu, Florida International University

Viyon Dansu is a PhD candidate in Engineering and Computing Education at Florida International University, Miami. His research focuses on the intersection of secondary STEM education and cultural practices in Sub-Saharan Africa. He holds a Bachelor's and Master's degree in Systems Engineering from the University of Lagos, Nigeria.

Dr. Ibukun Samuel Osunbunmi, The Pennsylvania State University

Ibukun Samuel Osunbunmi is an Assistant Research Professor, and Assessment and Instructional Specialist at Pennsylvania State University. He holds a Ph.D. degree in Engineering Education from Utah State University. Also, he has BSc and MSc degrees in mechanical engineering. His research interests include Artificial Intelligence in Engineering Education, faculty development, student engagement, evidence-based pedagogy, e-learning, broadening participation in STEM education, sustainable energy, and material characterization.

From Adoption to Inclusion: Shifting Teachers' Mindsets Through Technology Integration and Culturally Sustainable Pedagogy in STEM Education in Sub-Saharan Africa (Evaluation paper)

Abstract

The underrepresentation of Black students in STEM education remains a persistent challenge despite global efforts to promote participation and equity. In Sub-Saharan Africa (SSA), there is a need for STEM teachers to continue developing their digital literacy in designing technology-enhanced, student-centered lessons. However, it is important to note that the possession of technological skills alone will not necessarily promote inclusive learning outcomes. To achieve inclusive learning, the integration of technology must be informed by Culturally Sustainable Pedagogy (CSP), in which technology is seen not only as a tool but also as a resource designed to validate learners' cultural identities. This study presents an overview and evaluation of a professional development program designed to train thirteen (13) K-12 STEM teachers in SSA for dual integration of digital tools and CSP. The program consisted of an initial one-month intensive training in digital tools followed by a three-day CSP-focused workshop, emphasizing asset-based perspectives and culturally grounded instruction. Teachers explored CSP principles, including culturally inclusive teaching, use of cultural signposts, leveraging students' digital and social knowledge, and sustaining professional growth. A qualitative evaluation design using post-training questionnaires was employed to evaluate program impact. The thematic analysis revealed perceived improvements in participants' digital competence, confidence, ethical technology use (including artificial intelligence tools), and CSP application. Teachers reported moving from limited or hesitant technology adoption to intentional, inclusive STEM teaching.

Keywords: Technology integration, Culturally sustaining pedagogy, Inclusive STEM education, Teacher professional development, Teacher mindset shift, Artificial Intelligence.

INTRODUCTION

Persistent inequities in STEM education continue to limit meaningful participation for historically marginalized learners globally. In SSA, these inequities are evident in limited access to digital learning tools, low teacher digital literacy, and instructional practices that often ignore students' cultural knowledge [1], [2]. Traditional professional development programs frequently emphasize technical skills without integrating culturally responsive strategies, resulting in superficial technology adoption [3], [4].

Culturally Sustainable Pedagogy (CSP) reframes instruction to affirm students' cultural identities, languages, and lived experiences, shifting teachers from deficit-oriented perspectives toward asset-based practices [5], [6], [7]. Combining CSP with technology enhances STEM instruction by enabling culturally relevant simulations, digital collaboration, and adaptive assessments, fostering student engagement and higher-order thinking skills [8], [9]. Specifically, this study aims to:

1. Examine how professional development integrating CSP and technology influences teachers' perceptions of inclusive STEM instruction [5], [10].
2. Evaluate the effect on teacher confidence in using digital tools for student-centered learning[3], [11].
3. Investigate teachers' understanding and application of CSP following training[5], [7], [12].
4. Explore perceptions of the complementary role of technology and CSP in fostering inclusive STEM classrooms[12].

The study provides an example of pre-college STEM education in sub-Saharan Africa by examining the integration of culturally responsive teaching [13]. Sub-Saharan African secondary education systems, the focus of this study, do not typically offer engineering in the way it is explicitly integrated into the U.S. K-12 systems[14], [15]. As a result, this study considers the STEM classrooms as important spaces where foundational engineering thinking, including problem-solving and design-oriented reasoning, can emerge [16].

BACKGROUND

Technology Integration in K-12 STEM and Engineering Education

Technology integration has emerged as a prominent aspect of contemporary trends in STEM education as well as engineering education. Technology integration is increasingly being adopted to enable activities such as inquiry-based learning, modeling, simulation, and problem-solving [3], [9], [13]. In engineering education, technology integration enables students to solve real-world design problems, visualize graphical representations of abstract concepts, and solve problems through a simulation of real-world engineering design activities [13]. However, effective integration depends not merely on the availability of technology, but on a teacher's beliefs about teaching and learning with technology [4], [11]. In the Sub-Saharan region, the integration of technology in STEM education is not common due to infrastructure and capacity-building constraints, and the absence of policy support [2], [17], [18]. This restricted use limits the potential of technology to support engineering habits of mind such as systems thinking, creativity, and iterative problem-solving[13], [19].

In this study, engineering education is conceptualized not only as a standalone discipline but also as an approach to STEM learning that is often embedded in problem-based learning in the SSA context [16]. This framing holds particular significance in contexts like SSA, where formal engineering education at the K–12 level may be nonexistent.

The *Unified Theory of Acceptance and Use of Technology* (UTAUT) is a theoretical framework for examining teachers' adoption behavior towards technology [9]. While applying the UTAUT theory, it is observed that performance expectancy, effort expectancy, social influences, and facilitating conditions are determinants of users' behavioral intention to use technology. Professional development programs that simplify perceived complexity and enhance perceived usefulness have been found to contribute to sustained technology use [9], [20], [21].

Despite the recent focus on digital literacy, several studies have argued that the integration of technology is not necessarily a guarantee of equitable learning outcomes in STEM education [3], [22]. Technology integration without consideration of students' sociocultural context may reinforce inequalities or disengage students whose context is not addressed in the curriculum [22], [23]. This limitation underscores the need for pedagogical frameworks that intentionally foreground culture alongside technology.

Technological Pedagogical Content Knowledge (TPACK) and Teacher Preparation

According to the Tec*hnological Pedagogical Content Knowledge* model, technology integration should occur where content knowledge, pedagogy, and technology meet [8]. This means that teachers not only need to be able to use technology effectively but also to connect it with subject matter and students' needs. Studies have shown that teachers without a pedagogical framework tend to implement technology superficially, whereas teachers with a strong pedagogical model tend to implement it meaningfully [4], [11].

In SSA, gaps in teacher preparation programs often leave educators underprepared to develop TPACK competencies [23], [24]. Schlebusch et al. report that teacher education programs in Southern Africa frequently emphasize theory over practice, limiting opportunities for experiential learning with digital tools [22]. Similarly, Oubibi et al. highlights that many professional development initiatives focus on tool exposure rather than instructional redesign

[17]. TPACK has been criticized for not doing enough to address issues of cultural responsiveness, especially in a culturally diverse and postcolonial setting [5], [12]. This occurs when a teacher develops a technology-rich lesson plan that does not connect with the realities of the students' world. This criticism underscores the importance of grounding TPACK implementation within a culturally oriented pedagogical framework.

Culturally Sustaining Pedagogy in STEM Education

CSP can be considered an extension of culturally relevant teaching, focusing on sustaining students' cultural identities and practices within the school setting [6], [7], [12]. In contrast to the view that sees culture as a tool for bridging students into the mainstream of academic practice, CSP views culture as an integral part of the learning process. This shift is particularly important in STEM education, where dominant instructional approaches often privilege Western epistemologies and abstract representations [5], [7].

Renowned teacher educator, Ladson-Billings argues that culturally relevant pedagogy (CRP) must evolve to respond to changing sociocultural realities, a position that establishes CRP as one of the foundational frameworks upon which CSP is anchored and gives rise to what she terms "Culturally Relevant Pedagogy 2.0" [26]. In STEM contexts, this evolution involves connecting scientific and engineering concepts to students' communities, problem contexts, and ways of knowing. Paris and Alim further emphasize that sustaining students' cultural and linguistic practices is an act of educational justice, especially for historically marginalized learners[7].

In African contexts, CSP can be leveraged in alignment with the Ubuntu philosophy, which emphasizes interdependence, collective responsibility, and communal knowledge construction, enabling STEM teachers to ground instruction within the students' cultural frames of reference [5]. Dansu and Strong proposed a CSP framework for SSA STEM education that incorporates Ubuntu as a key element in arguing that asset-based perspectives can transform STEM classrooms into spaces where students' identities are affirmed rather than suppressed [5]. This framework highlights c*ulturally inclusive teaching*, the use of *cultural signposts*, *leveraging students' digital and social knowledge*, and *sustaining professional growth principles* that directly informed the CSP components and underpin this study's professional development program (Ogodo, 2024). However, many teachers report uncertainty about how to operationalize CSP in STEM classrooms, particularly when using digital tools [10]. This gap points to the need for professional development that explicitly models how technology and CSP can be integrated.

Professional Development for Inclusive STEM and Engineering Education

Effective professional development is sustained, context-sensitive, and practice-oriented [4], [25]. Short-term workshops that focus solely on tool demonstrations rarely result in lasting instructional change [3], [26]. In contrast, programs that combine extended training with reflective practice and pedagogical grounding are more likely to shift teachers' beliefs and classroom practices [4], [9]. In SSA, professional development initiatives increasingly emphasize digital competence but often neglect cultural responsiveness and inclusion [1], [17], [19]. Akongo et al. [19]suggested that while 21st-century skills are frequently cited in policy documents, teacher training rarely addresses how these skills intersect with equity and local contexts. In the same way, Naidoo & Singh-Pillay warn that digital approaches to teaching STEM may reproduce social injustice if the diversity of cultures and languages is not taken into account [22].

Recent studies have promoted professional development approaches that incorporate technology adoption theories, such as UTAUT, and culturally informed approaches to learning[5], [7], [12]. These approaches help teachers advance from adoption to inclusive, student-engagement-focused STEM education. This approach is particularly relevant for pre-college engineering education, where problem-solving, design thinking, and collaboration can be enriched through culturally relevant contexts and digital tools [13].

Purpose of Professional Development Effort

The growing global interest in technology integration, artificial intelligence (AI), and culturally sustaining pedagogies (CSP) has highlighted new opportunities to enhance STEM and pre-college engineering education. However, translating these ideas into meaningful classroom practice requires intentional professional training that supports teacher mindsets, confidence, and instructional capacity. Recognizing this need, our professional development program intentionally sequenced digital skill development, AI exposure, and CSP training to support teachers in exploring how these tools and practices could enhance inclusive STEM instruction in their contexts. In this evaluation study, we present the results of an analysis of teachers' post-training reflections to understand how professional development shaped their perceptions, confidence, and instructional intentions regarding technology, AI, and culturally responsive STEM teaching. This study further examines how these instructional shifts reflect the emergence of engineering-relevant competencies, including problem-solving and design-oriented reasoning, within STEM classrooms in Sub-Saharan Africa, thereby illustrating how engineering education is manifested in this context.

Description of the Professional Development Program Structure for STEM Educators

Thirteen middle and high school STEM teachers from diverse private and public schools in SSA participated in the program. The professional development program was a three-day workshop designed in the following manner: **Day 1** centered on digital tools with a focus on applying digital tools to lesson planning, engagement, assessment, and simulations. Teachers were trained on how to integrate technology into STEM lessons. **Day 2** addressed the role of AI in education and its ethical use for educational purposes. Practical sections on how AI can improve teaching and learning were conducted, and participants had hands-on experience using AI to support instructional design and support the inclusive learning experience of all learners using Universal Design for Learning (UDL) Principles. **Day 3** was an in-depth conversation about CSP as a lens for transforming teaching in STEM education. Teachers were introduced to ideas like culturally inclusive teaching practices, cultural signposts, drawing on students' knowledge, and maintaining professional development. Before the three-day workshop, STEM teachers participated in a one-month intensive training in digital tools to support STEM instruction.

EVALUATION APPROACH

This study is presented as an evaluation paper examining the impact of a professional development program. A qualitative evaluation design using post-training questionnaires was employed to explore teachers' perceptions, confidence, and CSP application. The study utilized thematic analysis [27]. The questionnaire was developed based on literature on professional development, CSP, and technology integration in STEM education. It was reviewed by two STEM education experts for clarity, relevance, and alignment with study objectives.

Data Collection

To evaluate the impact of the training on STEM educators who attended, a post-training questionnaire with reflective prompts was administered. Participation was voluntary, and consent was obtained regarding the dissemination of their responses from the evaluation effort. A total of 13 participants from SSA completed the survey. The questionnaire included confidence check multiple choice grid questions on using digital tools confidently, improving student engagement with tech, understanding what AI can do in the classroom, using AI tools for planning or assessment, using AI safely and responsibly with students, understanding what culturally sustainable pedagogy means, applying culturally relevant examples in lessons, and supporting diverse learners effectively.

Open-ended questions were included in the post-training questionnaire to capture participants' reflections after each day of the training sessions. Although the questions were slightly modified to align with each day's topic, they remained conceptually consistent and covered the takeaways and implementation plans related to the use of technology, AI, and CSP in STEM education, among other topics. The questions included:

1. What are the major takeaways from Day One on Educational Technology Tools?
2. What two to three things would you do differently as a result of today's session?
3. How would you describe your overall experience, and what feedback do you have to help improve future workshops?

Data Analysis

Using thematic analysis, responses were coded deductively by two trained educators with experience in qualitative analysis to identify patterns in confidence, mindset, ethical use of technology, CSP understanding, and inclusive STEM instruction using thematic analysis [27]. Throughout the analysis, the coders engaged in reflexive practices, and the findings presented reflect the consensus reached by both coders [27]. Initial coding was conducted independently by two researchers, who generated codes such as participants perceived *"increased confidence," "technology usefulness," "AI for planning," and "cultural relevance."* Codes were then compared and grouped into broader categories, which were iteratively refined into themes through discussion. Discrepancies in coding were resolved through consensus, ensuring alignment in theme development. An overview of the coding process, including examples of initial codes, categories, and the final themes, is presented in Table 1.

Table 1: Code-Theme Development Process

Initial code	Themes category	Final theme
Increased confidence, reduced fear, training clarity, and practical learning	Improved confidence and professional development experience	1. Professional Development Enhanced Perceived Confidence and Instructional Readiness
Intention to integrate technology, use of digital tools, and improvisation in low-resource settings	Technology use in teaching	2. Perceived Shift from Awareness to Intentional Integration of Technology in STEM And Engineering Teaching
AI for lesson planning, AI for student learning	AI Application	3. Artificial Intelligence (AI) For Teaching and Learning
Ethical awareness, data privacy concerns	Ethical considerations	4. Ethical Awareness and Responsible AI Use
Use of cultural examples, code-switching, native language use, and daily life relevance	Cultural pedagogy	5. Cultural Responsiveness in STEM Teaching
Student engagement, inclusion of diverse learners, and collaboration with colleagues	Inclusive practice	6. Perceived Movement from Adoption to Inclusion in STEM Education

Table 1: Development of Codes into Themes

RESULTS

The findings presented in this study are derived from a qualitative analysis of participants' post-training reflective responses. Themes reflect participants' self-reported perceptions, interpretations, and retrospective comparisons of their experiences before and after the professional development program. The analysis did not involve pre-post measurement of constructs such as confidence, readiness, or mindset, nor did it seek to quantify the prevalence of specific responses. Rather, the themes capture patterns of meaning evident across participants' reflections at the time of data collection. This analysis revealed six key themes reflecting their perceptions of the professional development program:

1. Professional Development Enhanced Perceived Confidence and Instructional Readiness
2. Perceived Shift from Awareness to Intentional Technology Integration in STEM and Engineering Teaching
3. Artificial Intelligence (AI) for Teaching and Learning
4. Ethical Awareness and Responsible AI Use
5. Cultural Responsiveness in STEM Teaching
6. Perceived Movement from Adoption to Inclusion in STEM Education

To ensure participants' anonymity, quotes will be referred to using participant identifiers (P1-P13).

Theme 1: Professional Development Enhanced Perceived Confidence and Instructional Readiness

Participants' reflections characterized the training as confidence-enhancing and a valuable professional development effort regarding their use of technology, AI, and culturally sustainable strategies. Many participants contrasted their pre-training experiences, described as marked by perceived low confidence, with their post-training reflections, where they reported greater feelings of readiness and empowerment. This shift in perception occurred multiple times as they narrated their experience. One participant related *"Before now, I was not confident, but now I am confident"* (P1). For some participants, the training also represented their **first impactful exposure** to technology- and AI-focused professional learning. One participant noted, *"This is the first online training I attended that really made sense"* (P4), while others described the sessions as "eye-opening" and "impactful" (P3, P12).

Furthermore, participants emphasized the clarity, simplicity, and practical delivery of the sessions, describing how these features contributed significantly to their perception of confidence building. "*The sessions were engaging, practical and easy to understand. I appreciated how each facilitator broke down different educational technology tools and demonstrated their real-life applications. The session increased my confidence in using technology for teaching and learning"* - P13 related.

Theme 2: Perceived Shift from Awareness to Intentional Technology Integration in STEM and Engineering Teaching

Participants expressed a shift in their perception of how they viewed the use of technology, from basic or optional use toward more meaningful integration. Participants described their previous perception of technology as difficult or optional and reflected on new ways in which it could be practical and useful. These reflections indicate participants' emerging awareness of how technology could be intentionally leveraged in STEM instruction. One participant noted, *"I see possibility in integrating technology in teaching in Nigeria"* (P12), while another reported, *"I will utilize the tech tools within my reach, use tech tools to teach students"* (P11)

Participants also described specific strategies to enhance teaching effectiveness, including lesson planning, simulations, assessment, and student engagement. This shift in perception were reflected in participants quotes such as *"I will use technology, prepare lesson plans and teaching materials and make my lessons more interesting"* (P1, P5, P2), and *"I will use digital tools to make what one is teaching relatable"* (P1). Others emphasized the educational value such instructional technological tools by saying that *"Tech tools make learning interesting and aid comprehension"* (P11), and *"I plan to integrate more digital tools into teaching"* (P12)

Importantly, several participants highlighted that meaningful integration was possible even in contexts with limited digital infrastructure. This perspective was articulated in reflections such as, *"The school does not have to be digitally sound before technology can be integrated"* (P4), and, *"I will improvise where needed; this can help in technology integration"* (P8) Collectively, these reflections indicate participants' emerging awareness of how technology could be intentionally leveraged to support STEM teaching and student engagement. The participants' use of technology for simulation reflects engagement with engineering education competencies, including computational thinking, abstraction, and systems modeling [38], indicating that technology integration may provide a foundation for embedding engineering competencies within STEM learning in Sub-Saharan Africa.

Theme 3: Artificial Intelligence (AI) For Teaching And Learning

Participants' reflections indicate that AI can support teaching and learning in educational contexts. Several participants reflected on what they learned during the workshop training on how AI can be used to improve teaching practices. For example, participants noted, *"I learned how making use of AI can make teaching interesting"* (P6), and *"AI can make tasks really simple"* (P3). Others reflected on how AI can support pedagogy and instructional design, including lesson planning, content generation, and personalized learning. As one participant shared, *"I will start using AI to support the creation of my lesson plans, generate examples, and provide personalized learning activities, which will help me work faster and teach more effectively"*(P2).

Similarly, many participants highlighted AI's role in supporting the facilitation of hands-on STEM experiences, noting that *"I will use AI to promote hands-on STEM learning and use it in my teaching"* (P1, P2, P5). Also, participants suggested that AI could facilitate student learning both in the classroom and during self-study by supporting exploration of challenging concepts and tasks as illustrated by this quote, *"Students can use AI to explore STEM concepts"* (P2). These reflections suggest that participants' perception of AI as a practical tool for enhancing instructional effectiveness and promoting student engagement in STEM learning improved as a result of the professional development effort.

Theme 4: Ethical Awareness and Responsible AI Use

The importance of responsible use of AI in STEM education emerged from the participants' reflections. Some of the participants reflected on the need for them to use AI responsibly, noting that “AI must be used responsibly” (P1, P6) and explaining that *“I will be careful about how I input sensitive information on AI tools”* (P3, P7). These observations indicate that while participants were aware of the benefits of AI in teaching and learning, they also considered ethical issues important. The participants felt that AI should aid in, but not substitute, critical thinking in the classroom, suggesting that ethical awareness was coupled with pedagogical concern.

Theme 5: Cultural Responsiveness in STEM Teaching

Also, participants’ reflections highlighted their increasing recognition of the role of culture in teaching and learning, particularly in STEM and engineering contexts. They described culturally relevant and culturally sustaining strategies as important tools for enhancing engagement, promoting inclusivity, and improving student understanding. For example, participants noted intentions to “*use different cultures that apply to my students to teach them effectively and make my class more interactive”* (P7), and to *“incorporate students’ cultural background into my lessons and build a more inclusive classroom environment”* (P9).

Others described culturally grounded practices as having the potential to positively influence student learning, reporting that they planned to *“improve ability to positively influence my students' learning by applying cultural examples and making use of their culture to help them understand my lesson”* (P7), and *“ increase the use of cultural materials to teach and increase students' interaction”* (P10). One participant explicitly connected cultural responsiveness to improved learning outcomes, stating, *“I will pay attention to CSP as this will facilitate learning in students”* (P4). Participants also emphasized connecting lessons to students’ daily lives as a strategy to make learning more relevant. P1 noted, *“relating lessons to students’ daily life improves understanding.”*

Furthermore, language emerged as an important cultural tool that supports communication and learning. Participants explained, *“using students’ native language helps learning”* (P6), and *“Code-switching helps students express themselves better”* (P9). Several participants noted that neglecting cultural context could hinder learning. They suggested that leveraging students’ backgrounds as instructional resources could make lessons more relatable and accessible. P3 related that *“language barriers should not be an issue in impacting knowledge, as the use of code switching and code mixing can, to a great extent, help knowledge”* (P3). These reflections indicate that participants increasingly recognized culture not as a barrier but as a valuable asset for enabling understanding and engagement in STEM education.

Theme 6: Perceived Movement from Adoption to Inclusion in STEM Education

Reflections made by participants commonly connected technology use and culturally responsive practices with inclusivity accessibility, and engagement enhancement. Participants noted their intention to *"integrate the use of smartphones and ICT tools to enhance science pedagogy"* (P5), and *"find ways to help my student get familiar with technological tools for their learning"* (P10).

Participants also described collaborative practices and professional learning communities as important for inclusive STEM teaching. One respondent explained, *"Any project I want to do in class, I will involve my fellow teachers for us to share ideas"* suggesting a recognition that inclusion can be supported through shared instructional knowledge and collegial collaboration. Other reflections highlighted specific strategies for supporting learners with unique needs or barriers, including language differences and varying levels of technological readiness. Participants noted that *"Students from all levels can be introduced to AI applications"* (P4) and that *"Technology helps overcome language barriers"* (P3), illustrating that participants viewed technology as a tool for broadening participation in STEM. From these reflections, the participants considered technology and culturally responsive practices as tools for enhancing inclusion and engagement in STEM classrooms, allowing teachers to address different learners' needs while promoting collaborative learning.

DISCUSSION

The results of this evaluation indicate that the professional development activity participants reported a perceived positive influence on their attitudes, confidence, and intentions in STEM education. In relation to this, based on the six themes, participants indicated improvement in confidence, mindset shift, integration of technology, use of AI, emphasis on ethical issues, CSP, and inclusive instruction. Findings from Theme 1 (Professional Development Enhanced Perceived Confidence and Instructional Readiness) and Theme 2 (Perceived Shift from Awareness to Intentional Technology Integration) highlight how participants described increased confidence alongside a growing intention to integrate technology more meaningfully into their teaching.[6], [28] has noted that professional development activities can encourage significant engagement with technology and CSP instruction.

These findings should be understood within the broader context of sub-Saharan African secondary education systems, where engineering is not typically offered as a distinct subject in the way it is explicitly integrated into U.S K-12 systems [14], [15]. As a result, engineering education in pre-college contexts is often embedded within STEM subjects. The outcome of this evaluation study suggests that engineering-relevant competencies are emerging within STEM instruction through AI integration and culturally sustaining pedagogy. This is reflected across Theme 2 (technology integration) and Theme 3 (Artificial Intelligence for Teaching and

Learning), where participants described using simulations, digital tools, and AI to support instructional design.

Teachers' reported practices, such as lesson simulation, contextual problem-solving, iterative instructional design, and adaptive use of digital tools. This closely align with foundational engineering education constructs, including systems thinking, design thinking, and problem decomposition [29]. As such, this study positions itself within engineering education literature by suggesting that engineering learning pathways may develop implicitly within STEM classrooms in contexts where formal engineering curricula are absent.

Participants described the training as a confidence-enhancing and professional reawakening experience, particularly in relation to digital tools, AI, and CSP. Reflections indicated that before the training, participants experienced low confidence. The reported post-training sense of readiness and empowerment underscores the value of experiential, hands-on professional development, as captured in Theme 1 (confidence and instructional readiness). Reflections on the part of the participants reveal a transformation in perceptions of technology from being optional or threatening to being useful and amenable to meaningful integration. This aligns with Theme 2, where participants began to envision technology not only as a supplement but as a tool to improve the planning, simulation, assessment, and engagement associated with learning and teaching.

Furthermore, the importance of professional development efforts in equipping educators and students in AI literacy skills cannot be overemphasized [30]. Through the professional development effort, participants realized how AI can be a helpful tool for their teaching activities and for engaging their students, aligning with the TPACK framework's emphasis on meaningful learning, where educators leverage technology to strengthen subject matter delivery while better addressing learners' needs. These reflections are consistent with Theme 3 (AI for Teaching and Learning) and Theme 4 (Ethical Awareness and Responsible AI Use). They demonstrated their commitment to applying AI in their teaching. It is evident from the reflections that learning technology skills and ethics can be done at the same time, thus justifying the need for applying AI effectively and ethically. In the classroom, the role of AI should be to aid the teacher's judgment.

Finally, participants increasingly viewed culture as an asset to be harnessed, not an obstacle, and incorporated CSP into teaching. This is reflected in the importance of tapping into students' culture, language, and experiences to improve engagement and understanding. The importance of flexibility in language, exemplified by code-switching, cannot be overemphasized in STEM education to overcome cultural and knowledge divides. This is reflected in Theme 5 (Cultural Responsiveness in STEM Teaching). [6], [10], [12] have suggested that culturally responsive teaching practices improve inclusion, motivation, and learning outcomes. Theme 6 (Perceived Movement from Adoption to Inclusion in STEM Education) shows that the participants related technology use and cultural responsiveness to STEM instruction. Participants connected technology use and culturally responsive practices to inclusive teaching. They highlighted strategies for engagement, accessibility, collaborative learning, and supporting learners with specific needs.

CONCLUSION

Overall, the findings provide evidence that teachers' perceptions of their confidence, autonomy, and awareness of ethical practices in STEM education can be increased through professional development activities that involve experiential learning, Artificial Intelligence, and CSP. Professional development activities should continue to focus on applications, scaffolding, and reflection to enhance technology use. The addition of ethical practices ensures that the use of technology does not increase inequality.

The relevance of targeted professional development for teachers of STEM and engineering subjects in Sub-Saharan Africa cannot be overemphasized. The teachers felt there had been an increase in teacher confidence, a change in teacher mindset towards purposeful technology integration, and an understanding of the ethical use of AI and culturally sustaining pedagogy. This shows that the targeted professional development will enable the teacher to employ innovative approaches within the classroom.

While this study focused on participants' immediate post-training reflections, future work will involve follow-up engagement with participants to explore their long-term implementation of technology integration and culturally sustaining pedagogies in their classrooms. Such longitudinal insights would provide a deeper understanding of how professional development translates into sustained instructional practice within diverse STEM contexts in Sub-Saharan Africa.

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