Empowering Rural Learners through ICT-Based STEM Education: A Case Study from Akpamu, Ghana

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Abstract: ***This study evaluates the implementation of a STEM education initiative at Akpamu Roman Catholic School in rural Ghana, aimed at enhancing digital literacy, creativity, and collaborative problem-solving among students. Using the UNESCO ICT Competency Framework for Teachers as a foundation, the intervention established an ICT lab and introduced project-based learning in digital environments, guided by university mentors. Sixty-six students participated in activities involving basic computer skills, digital research, and interactive learning. Qualitative methods, including observation and artifact analysis, revealed notable improvements in student motivation, technological confidence, and creative thinking. The paper underscores the transformative potential of early STEM exposure while identifying persistent infrastructural and policy-level barriers that limit rural education equity. It concludes with recommendations to support ICT integration and teacher development in line with Ghana's Education Strategic Plan (2018–2030) and the African Union's CESA 2026–2035 agenda.***

Keywords: STEM education, rural schools, digital literacy, ICT in education, Ghana education policy

1. Introduction

The rapid development of Information and Communication Technology (ICT) has altered economic, social, and educational systems worldwide, making digital competence a requirement for being an active member of a modern knowledge society. ICT does not focus solely on computers and internet access but instead incorporates a broad range of digital resources and information-processing capabilities, enabling business activities and services that enhance national socioeconomic development outcomes (Roztocki et al., 2019).

In the educational field, ICT, especially when integrated into the curriculum as Science, Technology, Engineering, and Mathematics (STEM), is regarded as an incentive for innovation, creativity, and problem-solving abilities, which are essential to economic competitiveness and technological progress.

Ghana has advanced substantially regarding the empowerment of ICT and STEM practices in the nation through reforms in ES education including the Education Strategic Plan (ESP) 2018-2030 and with international organizations dedicating resources to the area like UNESCO and the International Telecommunications Union. The programs highlight the national initiatives to increase digital literacy, enhance fair access, and equip students with the requirements of the twenty-first century workforce. However, there are still strong differences between the schools in the cities and schools in the countryside. People living in rural areas are still disproportionately marginalized because of the lack of proper infrastructure, sufficient bandwidth, teacher incompetence in the ICT sphere, and the inability to have access to digital devices-reasons that still deter successful introduction of STEM education (Kwasi & Andrews, 2018).

Such disparities are reflected among worldwide trends of digital inequalities, where disadvantaged section, especially as in distant areas, is disadvantaged in digital inclusion, consequently restricting both educational and economic opportunities. Since STEM education is currently linked to socio-economic growth, innovation, and professional prospects, equitable accessibility is critical to the national development policies. To address these issues, the current paper examines an intervention of STEM education in a rural community church school called Akpamu Roman Catholic Primary and Middle School in Ghana. This paper focuses on the effects of structured and practical learning with ICT support on student motivation, creativity, and the basics of digital literacy and determines systematic obstacles to the use of STEM learning in the rural setting.

This study is significant as it demonstrates how early and inclusive STEM interventions can bridge digital literacy gaps in marginalized communities, offering scalable insights for national education reforms and ICT integration strategies across sub-Saharan Africa.

2. Background of the Study

The digital divide is also a major challenge facing the provision of equitable education in Ghana and more so in the rural set up. Although the national policies mandate the adoption of ICT skills in the education system, very little population of basic schools in underserved districts have the active digital infrastructure. The inequality gap in ICT accessibility, including budget constraints, limited access to electricity, computers, and the internet, is a significant barrier to technology implementation, underscoring how ICT gaps specifically disadvantage rural schools (Kormos & Wisdom, 2021). Coexisting, the policy changes in the recent past have been the attempt to amplify the digital education ecosystem in Ghana. The overall education strategy of the government (Education Strategic Plan 2018-2030) and multiple collaboration efforts between the government and the companies have favoured the use of technologies in schools (Ministry of Education, 2018). Nevertheless, such initiatives are not evenly implemented at the ground level because the rural schools may not have the required infrastructure, and most teachers are not properly equipped to work with digital tools. Such structural constraints impede the prospects of the practice of hands-on and inquiry-based STEM pedagogies needed to develop innovativeness, problem-solving as well as scientific thinking. The digital vulnerability in the education system became quite evident during the COVID-19 pandemic. The fact that internet-enabled devices were less accessible and that internet connectivity was not reliable denied many basic school learners, particularly in rural regions, the opportunity to engage in remote learning, which further contributed to the increased inequalities in education. Absence of digital materials thereby does not only hamper adoption of STEM in available curriculums; it further contributes to losses in learning territories in remote areas. Further, the lack of physical infrastructure continues to exist in rural Ghana. Several institutions have crumbling classroom structures, poor seats, and lack of proper sanitation infrastructures, which hamper retention and participation rates among the students. These environmental challenges exacerbate technological deficiencies, making STEM interventions difficult to implement effectively. With these overlapping concerns, it is apparent that the situation is doubly unfavourable in Ghanaian rural schools: they do not have digital or physical infrastructure necessary to run effective STEM instruction. The rural schools encounter several challenges (e.g. poor infrastructure, teacher capacity, and inability to access ICT tools), although currently, their integration can be enhanced by the national reforms (Osei, 2024). The proposed research will address this challenge by evaluating a practical STEM intervention at a rural secondary school, trying to determine how a more focused ICT-based learning has the ability to increase the digital literacy, creativity and motivation of learners and identify the barrier to prompt intervention in the system that prevents the equitable adoption of STEM in rural education.

3. Theoretical Framework

The theoretical basis of the proposed research lies in the (United Nations Educational, Scientific, and Cultural Organization (UNESCO) ICT Competency Framework of Teachers (ICT-CFT) that offers an internationally known model of integrating the digital technologies in learning and teaching (see Figure 1). Recent versions of the model show the need to equip up to date classrooms with digital competence to enhance innovation, problem-solving, and learner-based pedagogies (Rakisheva & Witt, 2023). The framework provides six interrelated areas-understanding ICT in education, curriculum and assessment and pedagogy and digital tools and school organization and teacher professional development which are meant to assist educators in gradually adopting the technology-enhanced practices in instruction. ICT-CFT is operationalized by using three stages of development, which include Technology Literacy, Knowledge Deepening, and Knowledge Creation. Students, at the technology literacy level, gain background digital skills that are necessary to work with ICT tools. The further enhancement of knowledge is the use of these tools to investigate the fields of discipline, research, and resolve real-life issues (Takyi-Bondzie et al., 2022). The highest stage of digital competence is knowledge creation whereby knowledge is achieved through the use of the technology to design new solutions, come up with new ideas, and engage in meaningful community work. The recent studies highlight the applicability of the framework in enhancing the digital teaching capacity, especially in educational settings that have limited resources. Research indicates that ICT use changes learning environments, including the availability of digital competencies for teachers and students in education (Pajo & Wallace, 2001). Moreover, active learning, development of critical thinking, improvement of creativity are interrelated with competence-oriented ICT integration as they are among high-quality STEM education outcomes (Spyropoulou & Kameas, 2023). The ICT-CFT provides an organized framework to deal with digital gaps and promote early adoption of STEM in the situation of rural Ghana where the technological gaps are still acute. Its focus on progressive development of competency conforms to the national objectives stated in the Education Strategic Plan (2018-2030) and continental agendas including the CESA 2026-2035 plan set by the African Union. Following this structure, the current research will provide the satisfaction of ensuring that STEM teaching is technologically competent but pedagogically based, fair, and sensitive to the requirements of underserved students.

Purpose Statement

This paper aims to evaluate the impact of a structured, ICT-based STEM intervention on the digital literacy, creativity, and motivation of rural school students in Ghana, and to identify systemic barriers hindering equitable STEM access.

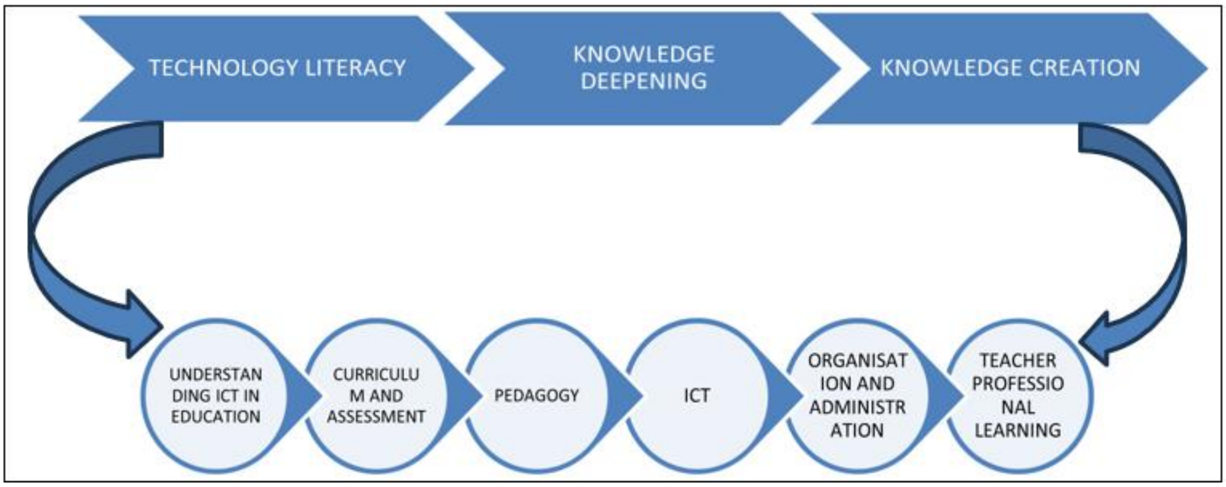

Figure 1: Authors Designed to Depict UNESCO 2011- ICT-Competency Framework for Teachers

4. Literature Review

Recent literature highlights the increasing significance of the Science, Technology and Engineering and Mathematics (STEM) education as the driver of national growth, innovation and technological preparedness. STEM education can help learners think critically, be creative, and solve problems, which are necessary to engage in the contemporary knowledge economies (World Bank, 2018). Systemic imbalances in Ghana and the rest of the sub-Saharan Africa do not help equitable access to high-quality STEM learning, at least in rural and under-served communities (Bardoe et al., 2023). A number of studies note that there are still some obstacles to the adoption of STEM in rural areas, such as a lack of infrastructure, lack of teacher preparation, and access to scientific and digital resources. The competence of the teacher is one of the key factors of successful implementation of STEM since the level of digital skills in an educator is a significant factor determining the capabilities of students to receive technology-improved learning. According to the recent analyses competence-based professional development systems would make teacher capacity building more effective and enhance comprehensive change in using digital opportunities in schools. Empirical studies also show that early consecutive participation in STEM produces motivation, creativity and achievement in students. Face-to-face, inquiry-based, and project-based teaching methods were found to improve the use of higher-order thinking and help learners to relate theoretical knowledge to practical use. In addition to that, involvement in STEM clubs, contests, and applied experiments will facilitate future career interest in STEM and facilitate disciplinary knowledge. Although improvements are made in the aspect of policy changes and national investment, the literature always concludes that rural learners are disadvantaged because of the infrastructures and unequal distribution of educational technologies. This disconnect demonstrates a pressing need to implement specific interventions that can offer the chance to deliver hands on, ICT-based STEM learning at the rural schools. The current paper enters this discussion and measures the effect of a rural digital connected STEM intervention in Akpamu, Ghana through evidence of how formalized digitally oriented interactions can empower motivation, inventiveness, and preliminary level expertise of STEM learners.

5. Methodology

The research paper used a qualitative research design and a practice-based STEM education intervention to understand how early ICT based STEM learning impacts on students in a rural school in Ghana. Creswell and Clark (2017) suggestions regarding the approaches to mixed method inquiry provided the format of the methodological approach, as it is grounded in recommendations that focus on real-life interaction, structured intervention, and reflective analysis according to the principles of educational inquiry.

5.1 Research Design

In this study, the researcher employed an intervention research design with qualitative approach in which the implementation and evaluation of a structured ICT-based program in STEM in the Akpamu Roman Catholic Primary and Middle School was conducted. The design enabled in-depth study of the motivation, creativity, digital literacy, and collaborative engagement of students. The teaching also involved project-based and practical STEM tasks aligned with the best practices that are mentioned in the literature on integrated STEM education (Chiang et al.,2022). An integrative review of literature on existing STEM models also contributed to designing the intervention, as the models were to be consistent in accordance with pedagogical frameworks that can be applied to the low-resource setting.

The area of the study was in Akpamu, a mountainous and farming community in Eastern region of Ghana that is rural. The location has been chosen since it has limited access to digital technology and has never had the STEM programs before. The study involved 66 participants in the Primary and Middle level of about 6-16 years of age and of various academic capabilities. Also, three university volunteers, who majored in ICT, Information Technology, and Computer Science, were instrumented as mentors and facilitators. As observers and support staff, classroom teachers were involved (MacDonald et al.,2020). The volunteer mentors were chosen for their knowledge and competence in STEM facilitation. The intervention structure included the establishment of an ICT laboratory with all its functions. The author of this research and the support team converted an empty space of the library into a computer lab with six computers four Ipads, broadband, productivity software (e.g. Microsoft Word, Excel, power point), games, typing software, educational software, and antivirus software installed. The computers were used as the main platform to run the STEM activities aimed at developing useful digital skills, innovation, and experimentation.

The intervention was based on the UNESCO ICT Competency Framework for Teachers (ICT-CFT) that presents the set of steps towards the integration of technologies in advance: the technology literacy, deepening of knowledge, creating of knowledge. The activities were structured in all of these levels starting with simple digital skills and leading to collaborative problem solving and innovation (see Figure 2). Three groups of students were created consisting of 22 students each under one supervisor. In the instructional approach, hands-on learning and project-based work, as well as collaborative problem-solving, were used, which are the strategies that Angana et al., (2025) proposes in order to transform the learning experience in STEM. The activities involved typing, web browsing, simple forms of digital research, basic playing of educational games, simple designing of basic digital projects, and solving structured STEM problems. These activities enabled learners to be creative, think critically, and socialize, which are often confirmed to help in integrated STEM studies.

Figure 2: The student collaborated with the mentors to gain hands-on experience

5.2 Data Collection Methods

It used the methods of qualitative data collection to observe changes in learner behavior, skill development, and attitudes. Mentors undertook regular observations of all instructional meetings recording student engagement, collaboration, motivation and behavior to solve problems. The researchers used observation records to record real-time data on how learners were interacting with technology and their developing competencies. Digital documents, simple projects, search tasks, game-based learning outcomes were included in the list of artifacts that were collected and analyzed to determine which concepts and technological skills the students have mastered. The use of reflective conversations and informal interview between the trainers and the students was to measure enthusiasm, self-efficacy, and the perception towards STEM learning. Reflective feedback was also given by teachers regarding impact of instruction and challenges experienced. The researcher field notes reflected both the contextual issues and the logistical issues coupled with insights into rural STEM implementation, according to the qualitative research guidelines (Creswell & Clark, 2016). Data analysis includes the evaluation of data was carried out using thematic analysis whereby patterns regarding motivation, creativity, digital skills, collaboration, as well as infrastructural issues could be identified. The themes were inducted based on recurring observations and student outputs. Results were also put into context with available literature on rural STEM education, digital instruction, and competence-based instruction within UNESCO ICT-CFT.

5.3 Ethical Considerations

Ethical practices were involved to seek approval of the school authority and to have voluntary participation. The identities of students were not documented, and all the information were treated on a confidential basis. The intervention was focused on making the intervention inclusive, with an equal opportunity of participation in all aspects of gender, ability, and grade levels.

5.4 Methodological Rationale

This approach was suitable since practical and participatory digital activities have been proved to empower STEM activities, especially in less-serviced regions (Barajas-Salazar et al., 2025). The study based the intervention on the UNESCO ICT-CFT and relied on evidence-based STEM strategies, which guaranteed the relevance of instructions, the scale in the case of instruction, and instructions responding to the national priorities of the Ghana education.

6. Discussion

The results of this paper show that exposure to ICT-based learning in STEM at an early age can significantly improve the motivation, innovativeness, and technological assurance of students in the rural Ghanaian schools. In line with the UNESCO ICT Competency Framework of Teachers, students would move through the process of basic digital literacy to higher visualization stages which are collaborative problem-solving and innovation (Akon-Yamga et al., 2024). These results corroborate the results of previous studies saying that formal, practical STEM education leads to inquisitiveness, critical thinking, and interdisciplinary comprehension. The practical, project-based framework of the intervention matches with the integrated models of STEM that focus on the real-world interaction and the practical aspect of learning. Also, the enthusiasm is very high, which confirms the claims by Manokore & Sibanda (2024) that, even early involvement in STEM activities can foster scientific interests in the long term.

Nevertheless, the project also revealed the existence of structural challenges that remain in place to limit STEM implementation in rural settings. Lack of appropriate ICT infrastructure, unstable electricity, and a low level of teacher digital competency reflects the presence of impediments in previous studies conducted in Ghana and other countries (Shamim et al.,2022). All these limits the scalability and sustainability of STEM innovations and serve to perpetuate the inequality between schools in rural and urban areas. Despite these challenges, the research shows the power of changes which well-organized STEM interventions can embrace. Volunteer mentors also emphasize the importance of teacher competence on learners. In general, the findings identify the relevance of early STEM education investment as a channel towards addressing the digital divide in Ghana and equipping rural students to engage in technology in the future.

7. Findings

The research results of this study are a holistic comprehension of how STEM learning in rural school children during early exposure to ICT can determine their level of motivation, innovation, digital skills, and teamwork abilities in Ghana. Based on a series of observations, student artifacts, reflective discussions, and thematic analyses, it had six generalizable findings, including (1) increased motivation and interest in STEM learning, (2) acquisition of useful digital literacy levels, (3) an intensified creative and innovative approach, (4) improved collaboration and communication, (5) evidence of talent growth and cognitively enhanced progress, and (6) the presence of embedded systemic obstacles that pose a threat of inequitable adoption of STEM. Combined, these results provide information about how organized online interaction can change the educational process of rural students and demonstrate more general policy and infrastructural limitations.

7.1 Higher Desire to learn STEM and motivation towards STEM

Among the most effective and the most coherent findings was the prominent nature of the growth in student motivation and interest towards STEM-related activities. Students showed excitement when they took part in practical lessons, they took part in learning activities willingly and also showed curiosity when new tools were introduced to them including typing games, basic coding activities, and online searches. Consistent with findings that exposure to STEM at an early age leads to higher intrinsic motivation and a positive attitude towards learning (Sahin et al.,2020). Several learners would talk of their eagerness to use computers in the first place, which was a transforming impact of the implementation of

ICT tools in schools where learners had never been able to access computers before. When paired with systematic instructions, the novelty of technology proved to be quite an effective stimulus to active learning. Generally passive students in a traditional classroom setting were more participatory in the STEM sessions. In addition, the motivational benefits were maintained throughout intervention, which indicates that digital engagement repeated is useful in normalizing STEM learning and lessening fear of technology. The finding supports the results of integrated STEM studies, which demonstrated that practical activity leads to long-term curiosity in science and technology disciplines.

7.2 Building Capacity to Digital Literacy and Foundational ICT Skills

The intervention has helped the students with the basic and intermediate ICT competencies significantly. At the program completion, students were capable of carrying out the basic functions including typing, working with a computer interface, simple internet search engine, education software, and creation of the basic documents in Word and PowerPoint as they are the parameters of the first stage of the UNESCO ICT Competency Framework-Technology Literacy- that focuses on the functional digital skills as the basis of knowledge enhancement. Learners who first had difficulties in moving a cursor or typing letters slowly developed into more complicated works of operating software and multimedia interaction. Critically, the results showed gains not by gender alone but by grade levels, which is contrary to what most people may have initially believed that rural students (particularly girls) are not technologically apt. This result is consistent with Timotheou et al. (2023), who state that learners with facility-facilitated access to digital means can enhance their digital capability. Generally, the growth of digital literacy is an essential cornerstone of future STEM education and digital engagement particularly in isolated environments where digital literacy is uncommon.

7.3 Enhanced creativity, innovation and problem solving

There were also strong results in creativity and innovative thinking by the students. Most learners explored digital tools on their own, created simple games, explored multimedia features and brainstormed about a digital project. There were students who went to the PowerPoint presentations animations, shapes and patterns, and typing programs to challenge themselves on the speed and accuracy assignments. This result is in line with the studies that point out the importance of early developmental involvement in STEM stimulation of creativity and higher-order thinking (Evripidou et al., 2020). The practical style facilitated the practice of divergent thinking because the students were free to explore digital environments. The project tasks involved a set of problems to be discovered and then solutions to those problems, which were digital, had to be offered and an evaluation of the outcomes or the results needed to be conducted like the Knowledge Deepening and Knowledge Creation levels of the UNESCO ICT-CFT.

The capacity to develop innovation was especially observed in the way students could relate new knowledge and previous experience. As an example, when students started perceiving computers as tools of entertainment and learning, they started to realize their useful purpose of researching, designing, and creating solutions to problems. It is a change that is indicative of the wider pedagogical importance of STEM education with regard to the development of cognitive flexibility and creative thinking.

7.4 Improved Teamwork and Interaction

The other important discovery is the increasing collaborative and communication skills of students that have grown considerably. Groups necessitated learners to work together, share work, exchange ideas, assist fellow students in problem-solving difficulties and combine their efforts to complete online tasks. The number of computers available in the lab was minimal and, therefore, peer collaboration was natural. Such a result has been shown by the literature endorsing that collaborative learning improves social skills, problem solving capacity, and STEM participation (Oguru & Amie-Ogan, 2024). Learners who were initially reluctant to collaborate finally learned to adapt to collaborating with their colleagues, learn to negotiate roles, and help each other. The questions that emerged were often answered, there was a tendency to ask clarifications, and to discuss their findings. The teachers witnessed that students developed some confidence on expressing ideas, and this is necessary to learn science later in their lives. The teamwork also enhanced inclusivity: pupils with better digital literacy would take the weaker ones on board and create a collaborative learning process instead of a competitive learning atmosphere.

7.5 Signs of Talent building and Cognitive Development.

The intervention has shown that a lot of students had great intuitive appeal towards technology and activities in the field of STEM. Some of the students expressed high curiosity, fast acquisition of digital tools, and innovative problem-solving abilities. This has been portrayed by their laggards, implying that the rural learners can harness much untapped potentials that can be mobilized when the opportunities and resources are availed to them. This observation confirms the theories held by Wan et al., (2021) that early introduction to STEM can help in discovering hidden talents and development of career-oriented interest. The fact that student talent is manifesting itself means that the difference in STEM achievement between the rural and urban students is more structural than cognitive. In addition, the intervention increased cognitive development because it prompted analytical thinking, pattern-identification, and sequential thinking, which are the basic skills in mathematics, coding, and engineering education. The metacognitive awareness showed in terms of the students' skills to decode digital feedback (e.g., scores in games, typing speed, messages displayed after completing a task, etc.).

7.6 Systemic Barriers to STEM Adoption That Are Nothing New

Although the intervention had great positive results, the results also show systemic issues that limit the implementation of STEM in rural Ghana includes a) ICT infrastructure; old or poorly maintained hardware, lack of suitable educational software, shortage of computers, lack of laboratory space and stability of electricity (Buabeng-Andoh, 2012).

Low digital competence by the teachers themselves that limits the adoption of sustainability of ICT, c) No internet access before intervention, and thus, there was no exposure to online learning materials, d) Lack of national level STEM policies at the local school level and unequal distribution of resources with the urban schools always getting a larger slice of technological assistance. These obstacles mirror the wider evidence throughout the African continent that the digital divide is localized in rural regions because of its monetary, infrastructural, and institutional inequalities. The fact that such challenges persist is an indication that rural STEM education needs multi-stakeholder investment with a long-term horizon. The summary of findings shows that all prove rural learners to be highly motivated, creative and talented in case they are provided with ICT-based learning of STEM. The planned intervention was able to enhance digital literacy, collaborative abilities, and reasoning. But, until the systemic barriers especially infrastructure and training of teachers, are handled, the scale of such interventions is constrained. These results indicate that early STEM education in rural settings can become transformative and that specific investments in this direction are imminent in accordance with the Education Strategic Plan of Ghana and the CESA 2026 2035 model of the African Union.

8. Conclusion

This paper shows that using ICT-mediated STEM learning in rural schools in Ghana is capable of considerably boosting the digital skills, creativity, and motivation of learners, regardless of the extreme resource's constraints imposed by the situation. The intervention case at Akpamu Roman Catholic School showed that with convenient and inquiry-based activities based on the frameworks of international competencies like the UNESCO ICT-CFT students acquire the base technological competencies rapidly and show significant progress in their problem solving and invention skills. These results confirm the international findings that an early exposure to STEM development can lead to development of the higher-order thinking and to the long-term attraction to the scientific and technological areas.

Along with these encouraging findings, the research also shows that there are still structural issues that create obstacles that hinder the long-term sustainability of STEM programs in rural schools. The poor technological infrastructure, lack of internet digital competence of teachers, as well as unstable electricity, are also some of the major barriers that inhibit the scale of such interventions. National and continental studies reflected in these challenges have found that rural schools are overrepresented about the lack of access to STEM resources and ICT-enabled methodologies. The rural learners will not have equal educational opportunities as those in the city without purposeful investment in their infrastructure, teacher training and monitoring machinery.

In general, the evidence highlights the disruptive nature of the target STEM interventions in eliminating the digital divide and enhancing inclusive education. Good performance and motivation among the students during the intervention suggests that rural students have the same ability to perform well in the STEM given that they have the right resources and pedagogic help. With Ghana working to its Education Strategic Plan (2018-2030) and tracking toward being a part of the CESA 2026-2035 agenda of the African Union, there is an impending need to make rural schools the focus of digital infrastructural expansion, the training of STEM teachers, and systems to monitor the advancement. By fortifying these systems, they will aid in academic achievement besides national innovation and socio-economic development and long-term technological resilience.

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