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Addressing Structural and Pedagogical Challenges in STEM Higher Education: Insights from Ghana

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ABSTRACT

Science, Technology, Engineering, and Mathematics (STEM) education is an important component in enhancing innovation, economic growth and general development of Ghana. However, higher education institutions in Ghana face many challenges that hinder the effective delivery and advancement of STEM programs. Through a comprehensive literature review, this study explores the challenges that Ghana's STEM Higher education faces. The study examines the causes and implications of these challenges and offers recommendations for improving them. The findings highlight inadequate infrastructure, lack of skilled teachers, outdated curriculum and lack of financing and research as challenges faced in STEM higher education in Ghana. It recommends the need for policy reform, teacher training, curriculum reforms and design, gender representation and infrastructural development to bridge gaps in STEM education and ensure equitable access and quality. The study may be relevant to STEM policymakers, researchers and educators.

Keywords: Ghana, Higher Education, pedagogical challenges, STEM education, structural challenges,

INTRODUCTION

The World Bank (2017) and other donor nations have started to shift their exclusive focus on basic education toward recognizing the importance of higher education. In Sub-Saharan Africa, progress has been made, with several African nations implementing forward-thinking policies to strengthen tertiary education systems (Bloom et al.,2014; Teferra & Altbach, 2004). However, compared to other parts of the globe, this progress remains modest, partly due to limited appreciation of the benefits of higher education on economic growth (Bloom *et al.*, 2014).

Given the centrality of higher education to national development, STEM-based higher education is particularly crucial. Knowledge and technological change are advancing rapidly—from social media and online banking to artificial intelligence, robotics, and high-speed transport. As Schwab (2016) and Xing & Marwala (2017) argue, such transformations are typically driven by STEM. In Ghana, STEM education underpins banking, international business and infrastructural development. Ghana's banking sector's adoption of digital banking systems has facilitated business transactions, while fields such as civil engineering, urban planning, and renewable energy are vital for sustainable infrastructure. (Liu et al., 2019). Well-trained STEM graduates and professionals provide innovative solutions to national challenges, thereby improving economic growth and quality of life.

Despite the significant investments by successive governments and funding bodies, STEM higher education in Ghana faces persistent challenges that constrain its ability to produce a skilled workforce required for innovation, development and participation in the global knowledge economy (Asare et al., 2021; World Bank, 2019). The gap between the demand for STEM professionals and the capacity of higher education institutions to meet this demand is a pressing concern.

Ghana, often recognised as a politically stable democracy of over 31 million people, has expanded access to education, but concerns remain about quality and the alignment of STEM programs with labour market needs. A systematic review of structural and pedagogical challenges is therefore crucial for identifying barriers, analysing their underlying causes, and exploring potential solutions. This study represents one of the few systematic literature reviews that focus specifically on STEM higher education in Ghana. By consolidating and critically analysing existing scholarship, it builds upon earlier research but distinguishes itself by highlighting both structural and pedagogical challenges in a single review. The guiding research questions are:

1. What are the major challenges faced by STEM higher education in Ghana?
2. How do these challenges affect the capacity of higher education to serve as a driver of national development?

LITERATURE REVIEW

STEM skills are in high demand globally, with governments emphasizing the development of a STEM-competent workforce to drive economic growth and innovation (Hossain & Robinson, 2012). Bloom et al. (2014) argue that investing in STEM higher education in Africa accelerates technical advancements, reduces the knowledge gap, and contributes to poverty reduction. Yet, in Ghana, the transformative potential of STEM higher education remains constrained by persistent systemic challenges.

Figure 1. STEM policies over the years, adapted from GSTEP report, 2022

Ghana's higher education system is diverse, consisting of universities, technical universities, polytechnics, colleges of education, and training colleges, each playing a role in developing specialised human capital (Boadu, 2021). Over the decades, reforms have sought to align higher education with national development goals, beginning with the establishment of the University College of the Gold Coast in 1948 and the Kwame Nkrumah University of Science and Technology in 1952, both of which became hubs for science and technology training (Bening, 2015). More recently, regulatory bodies such as the Ghana Tertiary Education Commission (GTEC) have been tasked with ensuring quality delivery across the sector (Act 1023, 2020).

Policy directions since independence have consistently emphasized the role of science and technology as engines of economic development. Kwame Nkrumah's post-independence agenda positioned universities as key to fostering indigenous innovation and industrial growth (Amankwah-Amoah, 2016). Subsequent reforms have sought to expand access and improve relevance, yet structural weaknesses in funding, infrastructure, and pedagogy continue to undermine the effectiveness of STEM higher education. Figure 1 shows reforms undertaken by different governments of Ghana over the years in STEM education.

Table 1: Key Studies and Policies on STEM Higher Education in Ghana

Author/Policy	**Focus**	**Main Contribution**
Bloom et al. (2014)	STEM higher education in Africa	Highlights the potential of STEM to reduce knowledge gaps and drive poverty reduction.
Bening (2015)	Historical development of higher education in Ghana	Documents the establishment of key institutions such as the University of Ghana and Kwame Nkrumah University of Science and Technology (KNUST).
Amankwah-Amoah (2016)	Post-independence STEM policy in Ghana	Shows how early policies positioned STEM as central to economic development.
Boadu (2021)	Structure of Ghana's tertiary system	Explains the roles of universities, technical universities, and colleges of education.
Act 1023 (2020)	Ghana Tertiary Education Commission (GTEC)	Establishes a quality assurance framework for higher education delivery.
Asare et al. (2021); World Bank (2019)	Contemporary STEM higher education challenges	Identify systemic issues: underfunding, skills mismatch, weak pedagogy, and limited research.

As shown in Table 1, existing studies converge on a few critical insights:

1. Despite Ghana's early commitment to STEM education, the country struggles to produce a STEM workforce that matches labour market demand;
2. Higher education reforms have often prioritised expansion over quality, resulting in mismatches between graduate skills and industry needs; and

3. Systemic barriers- including underfunding, limited research capacity, and inadequate pedagogical innovation- continue to constrain the sector's ability to drive national development (Asare et al., 2021; World Bank, 2019).

This synthesis highlights that while Ghana has laid important policy foundations for STEM higher education, the persistent gap between policy ambition and institutional capacity remains a central challenge. Understanding these issues is therefore crucial to positioning STEM higher education as a driver of innovation and sustainable growth in both national and international contexts.

RESEARCH METHOD

This study employed a Systematic Literature Review (SLR) to synthesise existing research on the challenges facing STEM higher education in Ghana. The SLR method, as outlined by Tranfield et al. (2003), ensures a rigorous and transparent approach and process for identifying, selecting, and analysing relevant literature. This approach was chosen because it allows for a comprehensive understanding of the body of knowledge while minimising bias.

Searches were conducted across reputable databases, including Scopus, Web of Science, and Google Scholar. The main search strings included: *"STEM and higher education"*, *"STEM in Ghana"*, *"STEM challenges Ghana higher education"*, and *"STEM pedagogy Ghana"*. Additional grey literature, such as policy documents and reports from organisations like the World Bank, was also reviewed to capture policy-level perspectives.

Through rigorous inclusion and exclusion criteria, the study included the following literature:

1. Peer-reviewed journal articles, policy documents, and credible reports published between 2000 and 2024.
2. Studies focusing on STEM education at the tertiary or higher education level.
3. Literature that examined structural, pedagogical, or policy-related challenges in Ghana.

On the other hand, the study excluded:

1. Studies focused on STEM education at the basic or secondary level.
2. Non-English publications.
3. Opinion pieces, blog posts, or sources without methodological rigour.

The review was conducted in four stages:

a. ***Initial search*****:** In the first stage, abstracts of retrieved articles from key strings were read to select the first set of relevant peer-reviewed articles, policy documents and reports.185 records were retrieved at this stage.

b. ***Duplicate removal***: 22 duplicates were excluded (n = 163).

c. ***Title and abstract screening:*** 102 studies were excluded for irrelevance (n = 61).

d. ***Full-text review:*** Full texts of selected studies were then read and screened to make the final selection using the inclusion and exclusion criteria. The results from the search were then further scrutinised to narrow down the number of articles to only the useful ones. A total of 34 studies were excluded for not meeting the inclusion criteria (n = 27). A total of 27 studies were included in the final analysis.

Inference was then made to investigate the challenges that exist in STEM higher education in Ghana. A data extraction form was developed to capture key information, including study focus, methodology, key findings, and relevance to STEM higher education in Ghana. Thematic analysis was then applied to identify recurring challenges, which were grouped into two main categories: structural challenges (e.g., funding, infrastructure, governance) and pedagogical challenges (e.g., curriculum, teaching methods, skills mismatch).

To ensure transparency, the study selection process is documented in a PRISMA flow diagram (Figure 2), showing the number of records identified, screened, excluded, and included at each stage.

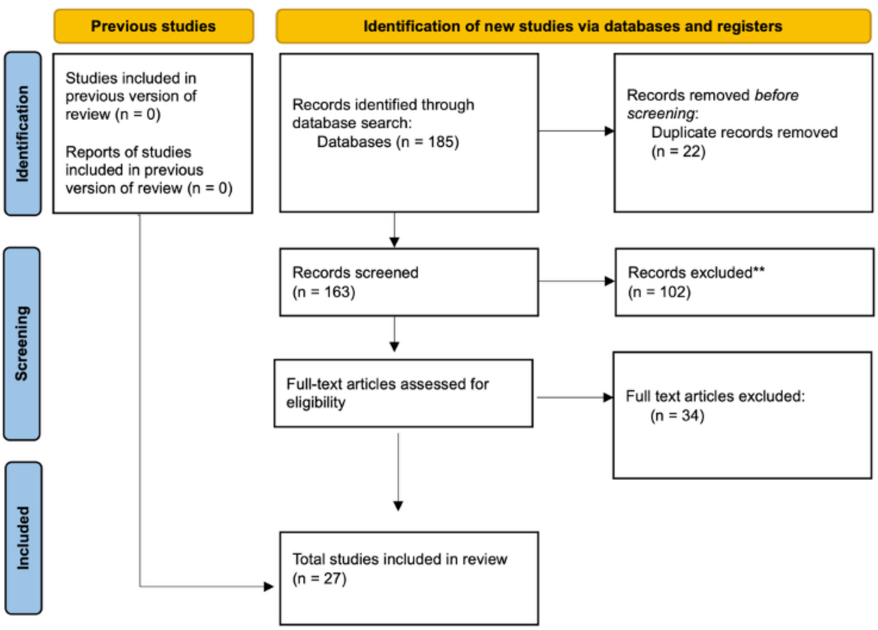

Figure 2. PRISMA flow diagram

FINDINGS

This review highlights the dual structural and pedagogical challenges facing STEM higher education in Ghana. While the importance of STEM for innovation and development is widely acknowledged (Bloom et al., 2014; Xing & Marwala, 2017), persistent systemic and instructional barriers limit the sector's effectiveness.

Structural Challenges

The literature consistently points to inadequate infrastructure and chronic underfunding as recurring obstacles (Practical STEM Education in Ghana, 2022b; Bardoe et al., 2023). The review shows that STEM higher education in Ghana faces systemic constraints that limit its effectiveness. Infrastructural deficits remain acute: only about 10% of institutions have functional laboratories, restricting practical training for STEM students (Practical STEM Education in Ghana, 2022b). Chronic underfunding compounds the problem, leaving institutions without adequate facilities, teaching tools, or research capacity.

Access and equity issues persist, with students from rural or low-income backgrounds facing barriers such as poor infrastructure and competitive entry requirements (Nkansah, 2021). Although access to education has advanced in the sector, there still exist socioeconomic, geographic differences and gender bias. Young women from economically underprivileged homes and those living in rural regions, have less chance of finishing their education. Gender disparities are also structural, as women remain underrepresented in STEM due to social norms and insufficient support systems (UNESCO, 2020).

Finally, weak policy coordination and governance undermine progress, with fragmented frameworks, bureaucratic delays, and limited monitoring reducing the impact of reforms (Akyeampong, 2017). Ghana currently does not have a clear and readily available national framework for STEM education. Usually, the existing educational policies show differences in their practical application. Effective application of educational reforms is hampered by bureaucratic delays, inadequate monitoring and evaluation, and a lack of collaboration among stakeholders.

These findings align with broader African studies that identify similar structural weaknesses but also reveal Ghana's relatively slow progress in policy coherence compared to peers such as South Africa (Teferra & Altbach, 2004).

Pedagogical Challenges

Pedagogical weaknesses further limit the potential of STEM higher education. A shortage of qualified faculty and limited professional development opportunities reduces instructional quality, while unfavourable teacher-student ratios often result in overcrowded classrooms (GNECC, 2022).

The curriculum frequently lags behind labour market needs, creating a mismatch between graduate skills and employment opportunities (Ofori, 2018). This misalignment is particularly problematic given the pace of technological change in STEM fields. Moreover, limited integration of experiential learning reduces students' capacity to develop critical problem-solving and technical skills. This mirrors global concerns about the need for agile, future-oriented STEM curricula (Darling-Hammond, 2017), but Ghana's case is particularly acute given the pace of technological change.

Figure 3. Conceptual model: structural and pedagogical challenges in STEM Higher Education in Ghana.

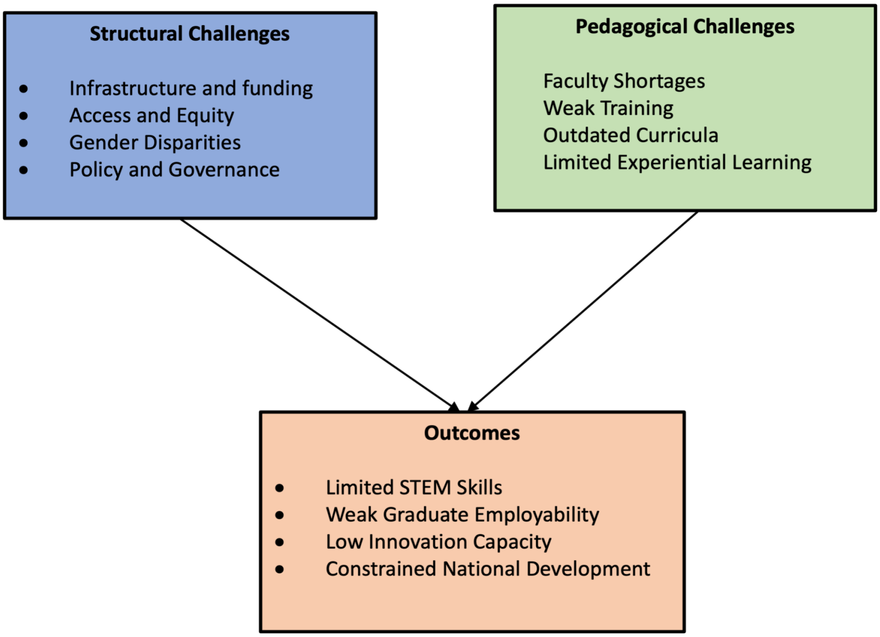

Figure 3. presents a conceptual model developed from the literature synthesis in this study. It illustrates the dual influence of structural and pedagogical challenges on STEM higher education in Ghana. Structural barriers such as inadequate infrastructure, inequities, and fragmented policies interact with pedagogical weaknesses, including underqualified faculty and outdated curricula. These interdependent factors constrain the development of STEM skills, limit graduate employability, and reduce innovation capacity. The model highlights the need for integrated interventions that simultaneously address structural and pedagogical dimensions to strengthen STEM higher education as a driver of national development.

DISCUSSIONS AND IMPLICATIONS

A clear pattern across studies is the interplay between structural and pedagogical barriers: weak infrastructure reduces opportunities for practical teaching, while inadequate faculty training limits effective curriculum delivery. However, contradictions emerge in the literature regarding policy direction. While some studies highlight government initiatives to expand STEM (Sam-Amoah & Frimpong, 2020), others emphasise the lack of a unified national framework (Akyeampong, 2017). A key gap is the limited empirical work on how students and faculty experience these challenges on the ground—most studies remain policy or institution-focused.

The findings have several implications. Structurally, there is a need for coherent STEM policies backed by adequate funding, equitable access measures, and gender-responsive frameworks. Pedagogically, reforms should prioritise teacher preparation, continuous professional development, and curricula aligned with industry needs, including emerging fields such as AI and renewable energy (Ozor et al., 2024). For practice, institutions must expand partnerships with industry to provide experiential learning opportunities. For research, more empirical studies are needed on student and faculty perspectives, as well as comparative analyses with other African contexts to identify transferable lessons.

Taken together, the evidence suggests that strengthening STEM higher education in Ghana requires simultaneous structural reforms and pedagogical innovation. Without addressing both dimensions, the potential of STEM to drive inclusive economic growth and position Ghana within the global knowledge economy will remain unrealised. The implications of the findings are as follows:

***Policy**:* In policy, it implies the formulation and implementation of policies aimed at enhancing STEM education to develop human capital. This makes it critical for the government of Ghana to make STEM policies more transparent and educate students of these policies. Additionally, policies should create favourable conditions for enhancing research and development and innovation infrastructure. Lastly, policies should foster a culture of science and technology within society. (Sam-Amoah & Frimpong, 2020).

Furthermore, policies need to empower both prospective and current women in STEM at educational institutions and workplaces to address gender gaps and promote the involvement, retention, and achievement of women in STEM fields.

Research: Research should explore the perspectives of women in STEM about how empowerment initiatives should be carried out, considering their gender experiences in their specific fields (Boateng & Nyarko, 2016). Redirecting the focus of the STEM model towards addressing stereotypes and cultural inhibitions is crucial for addressing gender, equity, and diverse needs in STEM education. This will not only help overcome these barriers but also open opportunities for increased female participation in STEM careers (Agyemang *et al.*, 2021). Policies should also include the promotion of fair and equal access to inclusive education in STEM higher education (Bardoe *et al.*, 2023).

It implies that public and private research institutes actively encourage outcome-based education and research by implementing a thorough curriculum revision (Biggs & Tang, 2011). To tackle the difficulties encountered by the youth in Ghana, research institutes should concentrate their efforts on initiatives that specifically address youth unemployment, job creation, and skill development (ILO, 2020). Their actions will provide information for policymaking that is based on evidence, resulting in initiatives that are focused and specific. Effective youth employment programs need collaboration across research institutions, government agencies, and development partners to be designed and assessed for their effects (OECD, 2018)**.** In addition, research institutes may provide data-driven insights into market demands and developing industries, which can help shape the creation of vocational training and educational curricula to meet industry needs.

Practice*:* In Ghana, it is acknowledged that there is a deficiency in practical scientific activities at all educational levels, including higher education. The absence of actual scientific equipment in schools and limited chances for experiential learning may have a detrimental effect on performance in science (Cullen *et al.*, 2019). Furthermore, it is recommended to prioritise investment in quality improvement measures such as instructors, infrastructures, and teaching and learning materials (TLMs), which are crucial to STEM education (Bardoe *et al.*, 2023). This will help students to engage in practical work that provides them with the chance to explore phenomena, make inferences, and refine their scientific skills in operating equipment, leading to meaningful scientific learning and the cultivation of critical thinking abilities. Science laboratory activities are crucial for equipping students with the necessary skills and knowledge to succeed in higher education.

Ghana needs to have highly skilled STEM educators and ongoing professional development for instructors. Consequently, it is necessary to examine the process of recruiting, developing, and training teachers (Darling-Hammond, 2017). Teacher training programs should prioritise the provision of a comprehensive skill development platform, where pre-service teachers may learn how to effectively incorporate the STEM approach into their teaching (Bybee, 2013). Effective STEM teacher education relies on teacher educators who possess the necessary skills to provide meaningful learning opportunities, offer constructive criticism, support teachers throughout their careers, and perform rigorous research to enhance educational theory and practice (Gess-Newsome et al., 2019).

It is prudent that a comprehensive curriculum reform be undertaken to include training in advanced technical and inventive skills that will be essential for future employment in fields such as artificial intelligence, data science, cyber security, agroforestry, agroecology, and others (Ozor *et al.*, 2024). Second, Ghana needs to consider the social dynamics and cultural surroundings when designing educational experiences and assessing outcomes. Ghana's cultural values, social expectations, and educational environment shape the methods and approaches used in STEM education (Ntim, 2014). Interventions should focus on more than just improving the curriculum. They should also work on improving social engagement and adapting educational methods to Ghana's specific cultural context, with the goal of raising STEM educational standards. Akon-Yamga et al. (2024) asserted that language plays a vital role in the mediation of cultural tools, enabling the development of advanced cognitive functions such as problem-solving, abstract thinking, and conceptual comprehension. These cognitive processes are particularly important in STEM education.

It is recommended to exert efforts to tackle socioeconomic inequalities, such as allocating more resources to schools in economically challenged regions and providing specialised assistance to underprivileged kids, which have been effective in reducing differences in academic performance (Osei,2024). In general, education policies that prioritise high-quality teaching, sufficient resources, and fair access tend to have a favourable impact on student results. For example, policies that prioritise the reduction of class sizes, provide professional development opportunities for teachers, and apply evidence-based instructional approaches have been linked to enhanced academic performance (Osei, 2024).

FUTURE RESEARCH DIRECTIONS

To advance STEM higher education research, this review highlights several gaps that future research should address to strengthen STEM higher education in Ghana. First, longitudinal studies are needed to assess the long-term effects of policy reforms, infrastructure investments, and teacher development initiatives on student learning and employability. Second, comparative research across African contexts could identify transferable practices while also clarifying Ghana-specific challenges. Third, in-depth studies on gender and equity are essential to design interventions that effectively address persistent disparities. Finally, future research should explore how curriculum reforms can integrate emerging fields such as artificial intelligence, data science, and climate-related technologies to prepare students for evolving labour market demands. An incisive exploration of extant literature reveals the multifaceted challenges embedded within the Ghanaian higher education system that impede the effective implementation of STEM education initiatives. Predominant among these challenges are inadequate infrastructure, financial constraints, and a paucity of qualified educators in STEM disciplines (Adjei, 2022). These constraints undermine the optimal development and deployment of STEM programs, thereby limiting their potential impact on economic growth.

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