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Prioritizing STEAM Education from the Start: The Path to Inclusive and Sustainable STEAM Education

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Abstract

This study highlights the significance of prioritizing STEAM (Science, Technology, Engineering, Arts, and Mathematics) education from the early stages of learning as a crucial step towards achieving inclusive and sustainable STEAM education. The study adopted a critical discourse analysis (CDA) and an allegory method entitled 'The Ancient Multi-Story Building'. The CDA involved studies, reports, and news on STEM-related and STEM initiatives in Ghana. The findings revealed a substantial gap in early childhood and primary education STEAM initiatives, largely due to prevailing misconceptions about these levels of education. The allegory of the 'Ancient Multi-Story Building' further explains the adverse impact of this gap by metaphorizing the flawed approach of initiating and investing in upper-level STEAM education while neglecting the lower-level years, much like a village constructing a multi-story building focusing on the higher floors without solidifying its base; obviously, the results will be disastrous. Similarly, the findings show that previous STEM-related initiatives in Ghana focusing on upper-level education have often been inclusively ineffective. The allegory further points out that the few students who thrive in these lopsided STEM-related pathways are typically those from affluent backgrounds with the necessary support. The study indicated that starting STEAM education in the early years of education has the potential to promote gender equity, cultivate critical thinking skills, and develop a positive attitude towards STEAM subjects among all young learners. This study, therefore, lays the groundwork to propose a strategic framework for early childhood and primary STEAM education in Ghana and other similar contexts.

Keywords: STEAM, STEM, Early childhood, Primary education, Ghana

INTRODUCTION

Originating from STEM, STEAM is an educational framework that underscores the criticality of familiarizing students with their environment through a comprehensive blend of five disciplines: science, technology, engineering, the arts, and mathematics to cultivate innovation, critical thinking, and creative problem-solving abilities (Ciftçi et al., 2022; Li et al., 2020). Researchers have echoed this framework and advocated for integrating STEAM principles into a nation's educational system at all levels, i.e., pre-K to graduate school. Embracing a STEAM-based approach is recognized for its potential to impart diverse skills among young learners simultaneously (Ministry of Education, 2018; Aktürk et al., 2017).

Ghana, mirroring the recognition of other developing nations, acknowledges the significant role of STEAM in driving the nation's economic and sociopolitical progress (Deming & Noray, 2020). To realize STEAM aspirations, the Ministry of Education (MOE) 2018 initiated the establishment of STEM high schools nationwide (MOE, 2018). The Ghana's

government is implementing these initiatives through the National Education Reform Secretariat (Anane-Amponsah, 2022). Following the Ghana Science and Tech Explorer Challenge Prize (GSTEP) in 2022, the Ghana Education Service is creating a manual on STEM education for junior high schools. These initiatives demonstrate the country's proactive commitment to embedding STEAM education into its core educational strategy (GSTEP, 2022).

While these initiatives are both noteworthy and commendable, positioning Ghana as a frontrunner in Africa for pioneering STEAM education (GSTEP, 2022) to tackle societal challenges and bolster economic development, there is little or no emphasis on STEAM in the early years of education (Early Childhood and Primary Education) (Ackah-Jnr et al., 2022). However, Ciftçi et al. (2022) stated that the National Science and Technology Council (NSTC) in 2013 highlighted a directive from President Obama advocating for the early integration of STEAM education. The focus of this study is to examine the relevance of introducing STEAM in the early years of education to ensure its inclusiveness and sustainability. Based on this objective, the following questions guided the study:

1. How have previous STEAM-related initiatives been effectively implemented in Ghana?
2. How critical and beneficial is the implementation of STEAM in Ghana's early years of education?

Children as STEAM Engineers

Children exhibit an innate curiosity about the world around them from the moment they are born, which extends beyond just science but encompasses the broader aspects of STEAM (National Research Council, 2014). Historically, there may have been an underestimation of children's capabilities as STEAM learners. However, recent insights suggest that children's knowledge and skills closely mirror the practices of real-world STEAM professionals (Barbarin & Wasik, 2009; Stephen & Edwards, 2017). This is based on their direct experiences and their daily activities, including conversations with family, hobbies, and media consumption (Stephen & Edwards, 2017). Schweingruber et al. (2007) emphasize that children's inherent capabilities are a valuable resource that should be harnessed and built upon during STEAM instruction. A paradigm shift is required in the education system to unlock this potential. Educators, especially those involved in K–8 STEAM instruction, are urged to reevaluate their pedagogical approaches, considering the current understanding of children's innate STEAM abilities (Ng et al., 2022). This assertion establishes a critical issue concerning the current STEAM initiative in Ghana, as it emphasizes older learners (JHS, SHS, and university students) and not children (early years of education).

Gardner's Theory of Multiple Intelligences and Constructivist Learning Theory

Howard Gardner proposed that intelligence is not a single, static IQ score but rather a dynamic array of different types of intelligence. These intelligences include linguistic, logical-mathematical, spatial, musical, bodily-kinesthetic, interpersonal, intrapersonal, and naturalistic (Hasanuddin et al., 2022; Pangesty et al., 2022). Children possess different strengths and ways of learning that can be tailored towards STEAM learning experiences (Wahyuningsih et al., 2020; González-Treviño et al., 2020). For instance, a child with strong spatial intelligence might benefit from visual aids and hands-on activities in a STEAM curriculum (Habibi, 2023).

In addition, the ideas of Jean Piaget and Lev Vygotsky on constructivism also posit that learning is an active process where children construct knowledge based on their experiences. This implies that rather than being passive recipients of information, children actively work to understand their world (Hebe, 2017). The study leans towards these two major theories to support the capabilities of children in learning STEAM education, as seen in Figure 1. STEAM education prioritizes hands-on, exploratory activities that align with constructivist theory and how children learn (Pass, 2004). The dominant learning approach for children is play-based (Hsiao & Su, 2021). Play is a natural way for children to explore, experiment, and understand their environment. Children will be engaged and motivated by incorporating play-based learning into STEAM education (Hsiao & Su, 2021; Habgood & Ainsworth, 2011).

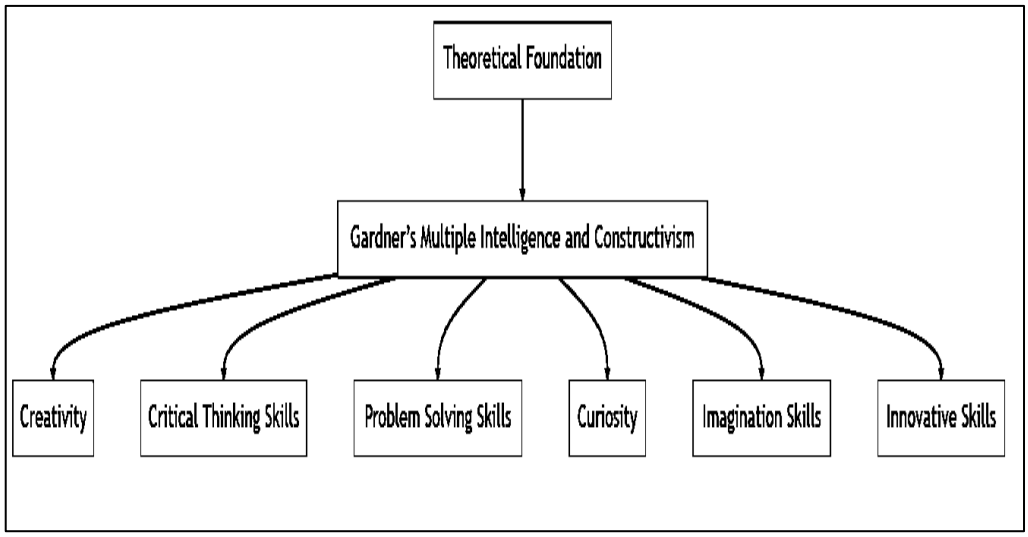

Figure. 1: Gardner's Multiple Intelligence and Constructivism

Early School Years: STEAM

Several studies have revealed a noticeable propagation of STEAM practices in the early years of schooling across numerous countries globally (Kayan-Fadlelmula et al., 2022; Gelir, 2022; DeJarnette, 2018), underscoring the international recognition of STEAM learning as a vital component of twenty-first-century early years education (Murray, 2019). Predominantly, most empirical studies have been centered in the USA (Li et al., 2022) and other European nations, including Sweden, New Zealand, Ireland, and Australia (Gelir, 2021; Hunter-Doniger, 2021). STEAM practices have also permeated various Asian countries, such as Saudi Arabia, Vietnam, and South Korea (Bui et al., 2023; Alghamdi, 2022; Delahunty & Rordáin, 2021). While the review process is comprehensive, it's notable that no research on STEAM during the early educational years was identified from an African country, despite Ghana often being heralded as a "pioneer" in the STEAM movement within the continent (GSTEP, 2022). This review section presents the STEAM acronym as predominantly the United States' educational innovation, emphasizing that the USA educational culture indirectly influences many other countries' educational goals (LeCompte, 2009; Alghamdi, 2022).

METHOD

This study adopted two qualitative approaches: critical discourse analysis (CDA) and allegorical analysis. CDA focuses on how discourse (written or spoken communication) is used to enact, confirm, legitimize, or challenge societal power structures (Kendall, 2007; Wodak & Meyer, 2009). The discourse under investigation in this study pertained to study reports and news on STEAM initiatives in Ghana (Amegah, 2022; GSTEP, 2022; Van Dijk, 2015). Primarily, the study focused on an official report detailing the practical implementation of STEAM education at the Junior High School (JHS) level in Ghana, as outlined in GSTEP (2022). Guenther (2023) suggests that allegorical analysis represents an innovative approach to research, enabling the depiction and comprehension of unique areas within a critical context through creative and imaginative means. The allegorical analysis in this study involved the 'Allegory of the Ancient Multi-story Houses' to vividly demonstrate the critical necessity of STEAM in the early years of education.

Current STEAM Initiative

The most recent STEM report that GSTEP presented to Ghana's Ministry of Education in April 2022 served as the basis for this study (Anane-Amponsah, 2022). The GSTEP was engaged in a three-year program working with 20,000 Junior High Schools (JHS) to explore the practical teaching of STEM at JHS. This study was conducted in the two largest regions in

Ghana, Greater Accra and Ashanti. The study also reported the plans of the ministry for achieving its STEAM dreams, captured as follows:

"2018, the Ministry of Education published the Education Strategic Plan 2018-2030. GES is developing a handbook on STEM education for JHSs (Ministry of Education, 2018). In consultation with Ghana Education Service, the National Council for Curriculum and Assessment (NaCCA) is developing a STEM curriculum and a handbook for Junior High Schools. However, the government of Ghana is already building 35 STEM Senior High Schools (SHS) and 5 STEM-based universities, as set out in the 2022 budget (General News of Sunday, 2021)". This investment intends to help bridge the gap between the demands of STEM industries and employers; and what is taught in high schools". (GSTEP, 2022, p. 9).

GES is actively working on creating a dedicated handbook for STEM education in JHS. This initiative aligns with NaCCA's effort to establish a comprehensive STEM curriculum and handbooks for JHSs. The government of Ghana is also making a substantial physical investment in this initiative. This clearly shows the ambitious project of constructing 35 STEM-focused Senior high Schools (SHSs) and 5 STEM-based universities, as outlined in the 2022 budget.

Analysis

To answer research question 1, the approach advocated by Van Dijk (2015) for CDA was adopted to interpret and explain previous STEAM-related initiatives. This involved a brief review of the existing literature on past STEAM initiatives in Ghana and their overall effectiveness.

To answer research question 2, the study incorporated the steps outlined by Guenther (2023) in allegorical analysis. These steps involved selecting and describing the Allegory that was pertinent to the study context, interpreting the Allegory within the context of its use, and subsequently engaging in discussions that unveiled the deeper meanings and implications embedded within the allegorical narrative.

RESULTS AND DISCUSSION

Trends of STEAM-related Initiatives in Ghana

In addressing the first research question regarding the historical implementation and effectiveness of previous STEAM-related initiatives in Ghana, we looked at STEM-related initiatives by the Ministry of Education as early as 1987. The focus of this initiative was to augment knowledge in mathematics, science, technology, social sciences, and technical skills, aiming to nurture students' creative potential, particularly at the **JHS and Senior** High School (SHS) levels (Biney et al., 2015; GSTEP, 2022). Subsequently, in December 2016, UNESCO, in collaboration with the Girls' Education Unit of the Ghana Education Service, organized the first science, technology, mathematics, innovation, and education (STMIE) clinic. This

initiative was to encourage **JHS students** to employ local materials to create products and models for exhibition, with the goal of fostering innovation (Mohammed et al., 2020).

Furthermore, in 2015, Ghana's Ministry of Education, in collaboration with UNESCO, published the ICT in Education Policy, emphasizing the necessity for teacher training in digital skills and the integration of ICT as a subject from primary school through high school (UNESCO, 2015). There have been a limited number of private organizations, such as STEMBees, GHScientific, and BSTEM (Basic STEM), that advocate for the integration of STEM education at the primary level (Takyi-Bondzie et al., 2023; Van Anh et al., 2022). Unfortunately, these initiatives fell short of their intended impact, as reported in Biney et al. (2014) and Mohammed et al. (2020) studies. Particularly, Mohammed et al.'s (2020) study revealed a lack of functionality in the STMIE program, with school administrators expressing concerns about its low participation and effectiveness. Private organizations are equally facing challenges in effectively implementing STEAM programs in the early years of school due to the lack of necessary logistical support required from the government (Takyi-Bondzie et al., 2023).

Critical Role of Early Years STEAM

In addressing the second research question, which revolves around the critical importance of early years STEAM education, we introduced a compelling allegorical narrative to explain the critical benefits:

The Ancient Multi-Story Building

The Ancient Multi-Story Buildings can be seen in Figure 2. The Allegory aimed to help the readers understand and appreciate the importance of education in the early years of life, which is usually not given enough attention, and this lack of focus adversely affects the quality and effectiveness of education at higher levels.

In an old, densely populated village, space became scarce. The village elders, keen on solutions, consulted experts from afar. After much discussion, they envisioned a novel idea: building houses atop one another, creating multi-story buildings (A Towering Dream).

In the excitement of this innovative concept, vast resources were poured into the project. Old houses were stripped of their roofs to accommodate this new design. However, in their haste and blinded by potential profit, the architects overlooked the importance of strengthening the existing foundations (Image A). They presumed it was a waste to invest in the old bases and they would suffice. Their towering dream became a reality with a nice erection atop the edifice.

To the villagers, these towering buildings were a symbol of triumph over their space constraints. Unfortunately, the inadequate foundations couldn't bear the weight, and the ground

floor collapsed (Image B), detaching the building from its foundation and making it hover above a pile of rocks and debris. To prevent mass accusations for their flaws, both the leaders and architects, accepted the buildings for use because many of the members were ignorant about what a multi-story building really looked like. The few members of the village with climbing abilities, and those with financial capabilities to afford a forklift, are the ones who get access to the buildings while the rest continue to blame themselves for not being able to climb. The Allegory emphasizes the importance of foundational elements if we truly want to promote inclusive education and advancement for all."

Figure 2: The Ancient Multi-Story Buildings

Table 1: Allegory's Key Terminology and Representations

Term	Meaning
The Ancient Village	A Country's Education System
Experts	Educational Authorities
Village Leaders	Government
Multi-story Building	School Systems (Levels)
Bedrocks (Foundation)	Early Childhood Education
Existing houses	Elementary Education

The Allegory of the village's multi-story buildings serves as a metaphor for the systemic issues within educational access and social justice. Just as the village elders overlooked the necessity of reinforcing the old foundations before erecting their towering structures, society often neglects the foundational education of its young citizens, especially those from underrepresented and low-income communities. This oversight leads to a risky situation where

the higher levels of education, represented by the upper stories of the buildings; become accessible only to the few who have the means or the rare ability to reach them, much like the villagers who could climb or afford a forklift. The result is a stratified system where Ivy League and other prestigious institutions are disproportionately populated by the affluent, while those from marginalized backgrounds find themselves unable to 'climb' due to early educational neglect. This imbalance perpetuates a cycle where the rich get richer, in terms of knowledge and opportunity, and the poor remain trapped in the lower levels of the socioeconomic structure.

Furthermore, the Allegory reflects on the broader implications for a society that prioritizes STEM and STEAM education at the higher education level without addressing the cracks in the early educational foundation. The image of the ground floor collapsing under the weight of the upper stories is akin to the failure of realizing a society rich in STEM citizens when the educational groundwork is shaky. Without a robust, inclusive early education system that equips all children with the necessary skills and knowledge, the dream of a technologically and scientifically advanced society will remain just that—a dream, hovering out of reach above a pile of unrealized potential. To truly triumph in the fields of STEM and STEAM, and to build a just and equitable society, the focus must shift to reinforcing the educational foundations, ensuring that every child, regardless of their socioeconomic status, has the support and resources needed to ascend to higher learning.

The Evolution of Early Childhood Education in Ghana Pre-2002 indicated a lack of institutions specializing in early childhood education (Morrison, 2002). There were 38 colleges of education at that time, but none focused on early childhood (Morrison, 2002). Early childhood care and education (ECCE) program at the University of Education, Winneba, followed the 2002 introduction of a two-year kindergarten program for 4-year-olds, which became a turning point in early childhood education by allowing teachers to specialize in early childhood education (Morrison, 2002; Agbenyega, 2008; Osseo-Asare, 2021). This evolution seems to have led to longstanding misconceptions and prejudices about early schooling in Ghana. For example, Jinapor (2014) studies found that the public and many educational authorities do not see why people should be trained with degrees to handle children in kindergartens. There is the perception that early childhood levels only sing songs and recite rhymes (Jinapor, 2014; Moloney, 2010). In 2017, a tragic incident occurred in Ghana where a dilapidated building collapsed, resulting in the untimely death of six kindergarten pupils who were sitting behind their classroom during a break time (Adom Online, 2017). On the other hand, in the same school, the JHS buildings were well established and renovated. This sequence

of events is a clear indication of how early childhood and primary education are regarded in Ghana.

Early childhood education, particularly STEAM initiatives, plays a pivotal role in instigating and nurturing curiosity, critical thinking, and creativity (3-Cs) among young learners (Nikolopoulou, 2022; Van Anh et al., 2022). Engaging young children in STEAM-related activities not only stimulates an energetic and explorative desire for knowledge but also fosters a developmental trajectory towards becoming innovative and analytical thinkers (Mohr-Schroeder et al., 2020; Wahyuningsih et al., 2020). This resonates with Ghana's early years education curriculum, which aims to cultivate individuals who are not only literate but also adept at handling complex problems, innovative in their thinking, and capable of actively contributing to the local and worldwide communities in which they live (NaCCA, Ministry of Education, 2019; Farwati et al., 2021; Li et al., 2022).

Initiating STEAM education from an early age strategically equips students with essential tools to emerge as adept problem solvers, a theme underscored across numerous research studies (Wahyuningsih et al., 2020; Bui et al., 2023; Ng et al., 2022). A pedagogical approach grounded in STEAM not only aligns with the natural curiosity and preferences of young children (John et al., 2018) but also presents them with opportunities to devise solutions to problems within a context that is both engaging and developmentally appropriate (Wahyuningsih et al., 2020; Bui et al., 2023). Moreover, the integration of regionally relevant cultural content into STEAM projects not only enhances students' awareness and engagement with their immediate communities and societies but also fosters an intrinsic connection between STEAM education and resolving issues pertinent to their local environments (Masud et al., 2023; Areljung & Günther-Hanssen). This fits with the core competencies outlined in Ghana's new standard-based curriculum. It stresses that teachers should give students the skills they need to approach and solve problems analytically. This will help students take ownership of their learning experiences and challenges (NaCCA, Ministry of Education, 2019).

Studies have shown the profound impact gendering processes exert on students' opportunities to both engage with STEAM subjects and pursue related careers at higher education levels. Men often demonstrate heightened commitment towards STEAM disciplines, excluding art, while women exhibit a more pronounced dedication to the arts yet often eschew STEM fields (Archer et al., 2012). However, early exposure to STEAM education, particularly during foundational schooling years, has the potential to disrupt these established patterns and foster a gender-parity discourse in STEAM (Areljung & Günther-Hanssen, 2022; Ng et al., 2022). Mulvey and Irvin (2018) further posited that even from a tender age, children can discern

the importance of adhering to their interests, thereby highlighting the need to nurture these career aspirations before stereotypical norms.

Children are competent from birth (Frimpong, 2021), and therefore early engagement with STEAM will not only spur motivation but also instill a positive attitude among young learners in STEAM courses in their subsequent academic pursuits (Johnston et al., 2022). Dejarnette (2012) articulates that initial involvement with STEM education can act as a catalyst, propelling children to opt for advanced STEM courses in subsequent educational stages and influencing their decisions to select these fields during high school and university (Bush et al.2020). The linkage between early exposure and future academic choices suggests a critical pathway through which young children can be inspired and encouraged to navigate towards STEAM fields in their subsequent academic and career pursuits (Ganira, 2022).

CONCLUSION

In this study, we adopted CDA and allegorical analysis to comprehensively examine STEAM initiatives in Ghana. The CDA was very helpful in critically evaluating both past and present STEAM-related initiatives. This showed that early year's STEAM education is often ignored while higher levels STEAM-related initiatives are given more attention, even though many of these have been shown to be ineffective (Mohammed et al., 2020). This recurring disregard for early and primary education appeared to be rooted in systemic prejudices towards early-year education.

On the other hand, the allegorical method served as a creative tool to vividly depict the critical importance of prioritizing STEAM initiatives in the early years of education. Without this consideration of early years education, the result will always be a stratified system where Ivy League and other prestigious institutions are disproportionately populated by the affluent, while those from marginalized backgrounds find themselves unable to 'climb' due to early educational neglect. The benefits of advancing STEAM education from the start include the promotion of gender equity, the cultivation of critical thinking skills, and the development of a positive attitude towards STEAM subjects among young learners. Without a robust, inclusive early education system that equips all children with the necessary skills and knowledge, the dream of a technologically and scientifically advanced society will remain just that dream, hovering out of reach above a pile of unrealized potential. To truly triumph in the fields of STEAM and to build a just and equitable society, the focus must shift to reinforcing the educational foundations, ensuring that every child, regardless of their socioeconomic status, has the support and resources needed to ascend to higher learning. One of the primary objectives of this research is to lay the groundwork for the development of a STEAM framework for early

childhood education and primary education in Ghana and similar countries. This framework will aim to empower young learners, foster inclusivity, and contribute to the advancement of STEAM education at all levels of education.

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