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Challenges to the implementation of STEM education in the Bono East Region of Ghana

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ABSTRACT

STEM education interrelates science, technology, engineering, and mathematics, ensuring that all interrelated contents are taught in coherence instead of in isolation. This promotes collaboration, critical thinking, and active engagement among students. The study ascertained the factors that compromise the implementation of STEM practices in the Bono East Region of Ghana to gain a moderately broad and deep understanding, allowing for a critical analysis of outcomes. It adopted a descriptive survey design to explore information concerning STEM education as it existed from May to October 2022. The study was carried out in Public Senior High and Vocational-Technical Schools in the Bono East Region of Ghana. The schools were split into STEM-related schools and non-STEM-related schools using a stratified sampling technique. Ten STEM-related schools were chosen using a purposive sampling method. 271 instructors from the departments of Science, Mathematics, and Information Communication Technology made up the study's population. A survey using a well-structured closed-ended questionnaire was administered online and the response obtained was transformed into frequencies and percentages in tabular forms using Microsoft Excel version 2016 (Microsoft, USA). Software Package for Social Sciences (SPSS) version 25 (IBM, USA) was used to perform a chi-square test to determine differences between responses obtained at the test significance of 5%. The study revealed that the general implementation of STEM practices throughout the studied Senior High Schools was below the mark. Inadequate STEM teaching-learning materials, limited certified STEM teachers, lack of STEM-dedicated infrastructure, inadequate professional development opportunities, absence of STEM documented standards and curriculum, limited access to technology, and limited time for teaching STEM-related subjects were some of the major factors contributing to the unsuccessful implementation of STEM practices in studied Public Senior High and Vocational-Technical Schools. Be that as it may, the study, therefore, recommended some measures including comprehensive STEM policies, adoptions of systematic STEM framework, and rigorous curriculum overhaul to be considered by the various stakeholders of education to realize the aspirations of inclusive STEM education.

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1. Introduction

Since the 18th century, STEM education has developed in response to the evolution of various scientific disciplines [1]. According to Ref. [2], literacy in STEM encompasses *"(1) understanding the functions of science, technology, engineering, and mathematics in contemporary society; (2) understanding at least some of the core ideas in each discipline; and (3) a fundamental degree of application fluency (e.g., the capacity to analyse the scientific or engineering content of news reports, carry out fundamental technological troubleshooting, and carry out fundamental mathematical operations used in daily life)."* STEM education comprehensively draws concepts from science, technology, engineering, and mathematics, making it essential for bridging the existing gaps between the four different fields by combining them into one unified paradigm [3]. Each STEM-related course contributes significantly to a well-rounded education. Students gain a deep awareness of their surroundings and how living things fit into the bigger picture through science. They are better equipped with technological skills to advance high-tech breakthroughs. Engineering improves students' capacity for problem-solving and content-to-context translation. Mathematics helps students develop their capacity for information analysis, error reduction, and thoughtful review while coming up with solutions. To this effect, all interrelated contents are taught in coherence instead of in isolation [4].

1.1. STEM education in Ghana

STEM practices promote students' pursuit of new ideas, concepts, or processes that meet a need in this 21st century [5]. This involves a high level of intuition, as it has a high tendency to breed innovative thinking. STEM-based knowledge and skills currently dominate the global economy [3] and as a result, it has gained massive global acceptance. According to Ref. [6], Ghana's economy has difficulty competing on a global basis. To curtail this, the Ghanaian Minister of Education, Dr Yaw Osei Adutwum, reportedly said that the government would improve STEM programmes to better prepare students for the job market after graduation, as reported by Ref. [3]. This assertion highlights how crucial STEM education is to Ghana's growth and sustainability.

Ghana has a total of 721 Senior High and Technical Vocational Schools [7]. There has been an increase in investment purposefully to ensure that Ghana achieves its STEM educational goals [8]. Questions about the types of policies needed to be implemented to accomplish the goals of inclusive STEM education are raised over time. About 20% of the total annual spending is on the public education system [9]. This has seen an influx with the onset of the Free Senior High School policy, ensuring the significant expansion of higher education in Ghana and the growth of vocational learning as a measure of bridging the unemployment gap. Hence it is necessary to implement steps to ensure that Ghana becomes a prominent hub for STEM education [3]. To this effect, the government of Ghana is

Table 1
Policy objective 2: Improved quality of teaching and learning and STEM at senior high schools.

Level	Policy objective	Key Problems to Address	Interventions
Senior Secondary Education	2.1: Increased use of quality TLMs and equipment in SHS	1. The target for the textbook–student ratio has not been achieved and has been declining: student–textbook ratio is about 0.50 for mathematics, science, and English textbooks 2. A large degree of regional variation in the provision of textbooks 3. Delay in producing textbooks when a new curriculum has been approved- Poor internet connection facilities in SHS 4. Inadequacy of computers and inadequate integration of ICT in teaching and learning at SHS 5. The introduction of free SHS will constrain existing resources	1. Invest in TLMs and equipment in SHS 2. Introduce in-school remedial tuition/support, particularly for SHS1, to improve learning outcomes and reduce repetition
	2.2: Improved learning outcomes for girls in all subjects, and all students in STEM subjects	1. Much lower enrolment in elective science and maths subjects compared to other courses 2. Large disparities in learning outcomes in the three northern regions compared to the rest of the country 3. Inadequate qualified teachers in STEM subjects	1. Invest in STEM materials and facilities to ensure SHS graduates are adequately prepared for tertiary institutions and the world of work 2. Invest in improving learning outcomes for girls in all subjects, especially STEM
	2.3: Improved quality and relevance of SHS curriculum and enhanced delivery of curriculum and assessment framework	1. The current curriculum has not been reviewed since 2010 to accommodate new pedagogical practices and ways of learning 2. Low teacher time-on-task 3. The proportion of teachers trained in SHS is 90%, but continuous professional development is necessary to ensure quality 4. The public perception that a high proportion of students are completing SHS without being functionally literate is becoming real	1. Improve the quality and relevance of the SHS curriculum 2. Enhance instructional practices of SHS teachers 3. Pilot a public-private partnership in SHS to improve the quality of learning outcomes through improved management and instructional leadership, and to inform the future roll-out 4. Strengthen assessment to inform instructional interventions

Source: Education sector Medium-Term Development Plan 2018–2030 [10] establishing 20 STEM centres and 10 new STEM Senior High Schools to create meaningful opportunities for the future.

1.2. Policy objective 2 of the Educational Development Plan 2018–2030

Table 1 presents *Policy Objective 2*: (Improved Quality of Teaching and Learning and STEM at Senior High Schools), highlighting key problems to address and the various interventions proposed to ensure that STEM education becomes fully operational in Ghanaian Senior High Schools. Though STEM education is gaining greater attention on a worldwide scale, Ghanaian educational stakeholders are still attempting to define it and figure out how to implement it. According to the Educational Development Plan 2018–2030 which is centred on the goal of improving education quality for all Ghanaians, every educational subsystem has a strategic purpose that is based on three policy objectives [10]. These policy goals are increased equitable access to and participation in inclusive education at all levels, enhanced teaching and learning quality and STEM at all levels, and sustainable and efficient management, financing, and accountability of education service delivery [10].

Ghana still lacks a comprehensive and easily accessible national framework for STEM education. From Tables 1 and it is obvious that a new integrated curriculum reform should place a higher emphasis on learning outcomes. The new curricula will be backed by Information Communication Technology techniques and will emphasise STEM education more strongly (and increase the provision of relevant science equipment). Investment in quality improvement strategies (teachers, infrastructures, and TLMs) will be a priority to ensure that increased government spending for Senior High Schools translates into learning results and does not worsen current imbalances [10].

It is also evident from Table 2 that the educational sector of Ghana has spent a total of GH' 674.6 million on improving the quality of teaching and learning and STEM at Senior High Schools across the country. On increasing the use of quality TLMs and equipment in the various Senior High Schools all across the country, a total of GH' 376.5 million has been spent from 2018 to 2021. Similarly, a total of GH' 231 million for 2018, 2019, 2020, and 2021, respectively, on improving learning outcomes for girls in all subjects, and for all students in STEM subjects. Finally, a total sum of GH' 67.1 million has been spent on improving the quality and relevance of the Senior High School curriculum and enhanced delivery of the curriculum and assessment framework. This is an indication that the Government of Ghana, in collaboration with the Ministry of Education, Ghana Education Service, and other stakeholders of education are working tirelessly to ensure that the full potentiality and benefits of STEM education across the country are achieved.

1.3. Statement of problem

Educational practices that are active, developmentally appropriate, collaborative, student-generated, contextual, engaging, and social give rise to deeper learning. Cross-curricular examination of STEM practices and standards gives light to effectiveness in developing higher quality learning befitting the needs of 21st-century learners. Traditionally, in Ghana, STEM-related courses have been exclusively taught in many schools by teachers who have specialized in each field with little overlap between the four disciplines. This has called for an emerging consensus regarding the need to merge all four disciplines to ensure effective practices and application, providing the opportunity to shape educational practices by taking advantage of this new paradigm. This requires integrating multiple theories from disciplines such as health sciences, robotics, programming, informatics, and agriculture and merging them into a successful approach. However, factors such as a lack of a definitive STEM model or framework, and inadequate STEM infrastructure, among others, have led to ineffective implementation of STEM education. Not only does this lead to poor engagement or interest, but also students do not contemplate promising careers in STEM after school. To advance STEM education, it is necessary to understand the reality of STEM implementation through the perspectives of various stakeholders, of which teachers are inclusive [11]. This study, therefore, ascertained the factors that compromise the successful implementation of STEM practices in Public Senior High and Vocational-Technical Schools in the Bono East Region of Ghana to gain a moderately broad and deep understanding, allowing for a critical analysis of outcomes. This will provide descriptive accounts of how teachers are connected to or familiar with STEM practices and standards. It will also provide a significant understanding of the effectiveness of governmental policies towards the implementation of STEM education and challenges regarding infrastructure, resources, curriculum, and professional development opportunities for teachers. The study also recommended a STEM integration framework in order to provide a more significant contribution to STEM implementation.

Table 2
Costs (in GH' Million) of interventions to support Policy Objective 2 from 2018 to 2021.

Policy Objective: Improved Quality of Teaching and Learning and STEM at Senior High Schools	Year				
	2018	2019	2020	2021	Total
2.1: Increased use of quality TLMs and equipment in SHS	87.0	89.2	97.4	102.9	GH' 376.5 million
2.2: Improved learning outcomes for girls in all subjects, and all students in STEM subjects	57.3	57.6	57.9	58.2	GH' 231 million
2.3: Improved quality and relevance of SHS curriculum and enhanced delivery of curriculum and assessment framework	12.0	8.3	10.1	36.7	GH' 67.1 million

Source: Education Sector Medium-Term Development Plan 2018–2030 [10]

1.4. Research question

What are the factors compromising the integration and implementation of STEM educational practices in Public Senior High and Vocational-Technical Schools in the Bono East Region of Ghana?

2. Methodology

2.1. Study design

The study used a descriptive survey, which was suitable for gathering information about events before organizing, tabulating, displaying, and describing the data collected. An online Google Survey Form (Google LLC, Mountain View, CA, United States) was shared with the Heads of Departments to be disseminated through the official WhatsApp platforms of the selected schools' Science, Mathematics, and Information Communication Technology (ICT) Departments. This was after the questionnaire was read and approved by the Headmasters and Heads of Departments of the 10 selected schools. Participants were informed that the information collected from them would only be utilised by stakeholders to make policy decisions. Additionally, participants were informed that their participation in the study was voluntary, that there were no known dangers, and that they had the right to withdraw at any time. The results were not provided along with any personally identifiable information, such as participant and affiliated school names taken from the surveys.

2.2. Area of the study

The study was carried out in ten Public Senior High and Vocational-Technical Schools selected from eight cities, all in Bono East Region. These cities are; Amantin, Atebubu, Jema, Kintampo, Nkoranza, Prang, Techiman, and Yeji.

2.3. Population

271 teachers from ten Public Senior High and Vocational-Technical Schools made up the study's population. The teachers belonged to the Science, Mathematics, and Information Communication Technology Departments.

2.4. Sampling technique

All Public Senior High and Vocational-Technical Schools were initially split into science/technical-related schools and non-science/technical-related schools using a stratified sampling technique. Ten science/technical-related schools were chosen using a purposive sampling technique. Afterwards, 271 teachers responded to the questionnaire based on convenience.

2.5. Instrumentation, data collection, and analysis procedure

Secondary data on *Policy Objective 2* (Improved quality of teaching and learning and STEM at all levels of education, Ghana) and costs of interventions to support policies of the Educational Development Plan 2018–2030 was obtained from Ref. [10]. A survey using a well-structured closed-ended online questionnaire was sent to the Headmasters and was shared with the Heads of Departments to be disseminated through the official WhatsApp platforms. The questionnaire was primarily structured into three sections to address specific questions as shown in (https://forms.gle/prVcDKBw4b8f8Edj8). The table for the demographic characteristics of teachers was organized in themes such as Gender, Age, Academic qualification, and Years of active service. Equally, the table for teachers' perspectives on the implementation of STEM educational practices was organized in themes such as Familiarity, Connection, Introduction, Integration, Instructional time, Awareness of STEM curriculum and standards, STEM laboratories, Technology, Certified STEM teachers, Professional Development Opportunities (PDO), and Career and Technical Education (CTE). The data obtained from the online questionnaire (Google Survey Forms) were collated from pie chart responses to frequencies and percentages using Microsoft Excel version 2016 (Microsoft, USA). Software Package for Social Sciences (SPSS) version 25 (IBM, USA) was used to perform a chi-square test to determine differences between responses obtained at the test significance of 5%.

2.6. Approval for study and data collection instrument

This study was approved by the Headmasters of the selected schools. The protocol for the study, including the data collection instrument (questionnaire) was sent to the Headmasters of the 10 Senior High Schools. The consent form was endorsed and signed by the Headmasters of the selected schools, signifying approval for the commencement of the study.

2.7. Consent for teacher participation

Since participants did not provide biological data or undergo any sort of physical or medical intervention, there was no physical risk related to the study. After approval, permission was granted by the Headmasters of the 10 Senior High Schools through the various heads of department to engage the teachers to seek their consent, provide highlights of the overall research process, data collection methods, and instrument (questionnaire), and also clarify if participation in the study was voluntary or compulsory. Teachers were made aware that the data gathered through the questionnaire would only be used to make policy decisions. Additionally, participants were made aware of the study's voluntary nature, the absence of any known risks, and their right to discontinue at any time. No personally identifiable information, such as participant names obtained from the surveys, was provided with the results. Before making any observations, queries regarding any potential issues were also directed toward the Heads of Departments of the studied schools.

3. Result

3.1. Demographic study of teachers

Table 3 presents the demographic study of teachers stratified by gender, age, academic qualification, and years of active service. Of all teachers (n = 271), [70.5%, n = 191] were males, whereas 29.5% (n = 80) were females. Again, the ages of the teachers ranged from 18 to 60 years, with the majority [45%, n = 122] aged between 36 and 40 years. Academically, [70.5%, n = 191] of the teachers have bachelor's degrees while [29.5%, n = 80] have a master's degree. Finally, [80.8%, n = 219] of the teachers have spent more than two years in the teaching service, whereas [19.2%, n = 52] have spent less than one year in teaching.

3.2. Teachers' perspective of STEM educational practices

Table 4 presents teachers' perspectives on the implementation of STEM educational practices in their respective schools. It focused on eleven thematic areas including; familiarity with STEM education (**Familiarity**), connection with STEM education (**Connection**), introduction to STEM education (**Introduction**), integration of STEM subjects as an additional course (**Integration**), time for teaching science as a result of STEM education (**Time**), awareness of STEM curriculum (**Curriculum**), awareness of STEM standards (**Standards**), presence of dedicated STEM laboratory (**STEM laboratory**), incorporation of technology in STEM-related subjects (**Technology**), certify teachers in STEM education (**Certification**), professional development opportunity (**PDO**), and students' involvement in career and technical education (**CTE**).

3.2.1. Familiarity, connection, and introduction to STEM education

As presented in Table 4, the majority of the teachers [92.3%, n = 250] were familiar with STEM education, whereas a few representing [7.7%, n = 21] were not familiar with STEM education. Moreover, [70.8%, n = 192] of the teachers indicated that STEM education has reached them and hence has a connection with STEM education. On the contrary, [29.2%, n = 79] of teachers indicated that STEM education has not reached them and has no connection with STEM education. Furthermore, the majority of the teachers [73.4%, n = 199] highlighted that STEM education has not been introduced in their respective schools, whereas [26.6%, n = 72] of the respondents mentioned that STEM education has been introduced in their schools.

As indicated in Table 5, there were significant differences between teachers who were familiar with and had a prior connection with STEM education and teachers who were not familiar and had no prior connection with STEM education ($p < 0.05$). There is also a statistically significant difference between teachers who indicated that STEM education has not been introduced in their schools and teachers who indicated that STEM education has been introduced in their schools ($p < 0.05$).

3.2.2. Integration, instructional time, and awareness of STEM curriculum and standards

Referring to Table 4, [73.1%, n = 198] of the teachers revealed that STEM education has not been integrated as a somewhat additional course in their schools, whereas [26.9%, n = 73] of the respondents indicated that STEM education has been integrated as an additional course in their schools. Moreover, the majority [52.8% (n = 143)] of teachers indicated that there was adequate time for teaching science as a result of STEM education. As opposed to this [47.3%, n = 128], respondents mentioned that there was no adequate time for teaching science as a result of STEM education. Additionally, most of the teachers [70.5% (n = 191)] were not aware of the STEM curriculum, whereas [29.5% (n = 80)] indicated that they were aware of the STEM curriculum (as shown in Table 4). Finally, the majority of the teachers representing [81.9%, n = 222] were not aware of the STEM various standards, with a few representing [18.1%, n = 49] being aware of the STEM standards (as presented in Table 4).

From Table 5, there is a considerable significant difference between teachers who indicated that STEM education has not been

Table 3
Demographic study of teachers.

		Frequency	Percentage
Gender	Males	191	70.5
	Females	80	29.5
Age	Between 26 and 35 years	88	32.5
	Between 36 and 45 years	122	45
	Between 46 and 60 years	17	6.3
Academic Qualification	Bachelor's Degree	191	70.5
	Master's Degree	80	29.5
Years of Active Service	Less than 2 years	219	80.8
	More than 2 years	52	19.2

Table 4
Frequency (n) and percentage (%) distribution of teachers' perspective on STEM educational practices.

Theme		(n)	(%)
Familiarity	Yes	250	92.3
	No	21	7.7
Connection	Yes	192	70.8
	No	79	28.8
Introduction	Yes	72	26.6
	No	199	73.4
Integration	Yes	73	26.9
	No	198	73.1
Instructional Time	Yes	143	52.8
	No	128	47.3
Curriculum	Yes	80	29.5
	No	191	70.5
Standards	Common Core State Standards for Mathematics (CCSS), International Society for Technology in Education (ISTE), Next Generation Science Standards (NGSS),	49	18.1
	None	222	81.9
STEM Laboratory	Yes	69	25.5
	No	202	74.5
Technology	Yes	106	39.1
	No	165	60.9
Certification	Yes	10	3.7
	No	261	96.3
PDO	Yes	74	27.3
	No	197	72.7
CTE	Yes	94	34.7
	No	177	65.3

Table 5
Interactive chi-square test for teachers' perspective on STEM educational practices.

Theme		Observed	Expected	χ2	DF	p
Familiarity	Yes	250	135.5	193.509	1	0
	No	21				
Total		**271**				
Connection	Yes	192	135.5	47.959	1	0
	No	79				
Total		**271**				
Introduction	Yes	72	135.5	59.517	1	0
	No	199				
Total		**271**				
Integration	Yes	73	135.5	57.657	1	0
	No	198				
Total		**271**				
Time	Yes	143	135.5	0.83	1	0.36
	No	128				
Total		**271**				
Curriculum	Yes	80	135.5	45.465	1	0
	No	191				
Total		**271**				
Standards	Common Core State Standards for Mathematics (CCSS), International Society for Technology in Education (ISTE), Next Generation Science Standards (NGSS)	49	135.5	110.439	1	0
	None	222				
Total		**271**				
STEM laboratory	Yes	69	135.5	65.273	1	0
	No	202				
Total		**271**				
Technology	Yes	106	135.5	12.845	1	0
	No	165				
Total		**271**				
Certification	Yes	10	135.5	232.476	1	0
	No	261				
Total		**271**				
PDO	Yes	74	135.5	55.827	1	0
	No	197				
Total		**271**				
CTE	Yes	94	135.5	25.421	1	0
	No	177				
Total		**271**				

integrated and teachers who indicated that STEM education has been integrated as a somewhat additional course in their schools ($p < 0.05$). Additionally, there is no significant difference between teachers who indicated that there was adequate time for teaching science and teachers who stated that there was no adequate time for teaching science as a result of STEM education ($p > 0.05$). Finally, there is a significant difference between teachers who were not familiar with the STEM curriculum and standards and teachers who were familiar with the various STEM curricula and standards ($p < 0.05$) (as presented in Table 5).

3.2.3. *STEM laboratory, technology, certified teachers, professional development opportunities, and career and technical education*

Additionally, the majority of the teachers [74.5% (n = 202)] mentioned that there were no STEM-dedicated laboratories to facilitate STEM activities in their various schools, while [25.5%, n = 69] mentioned that there were STEM-dedicated laboratories in their schools (as presented in Table 4). Also, 60.9% (n = 165) of the teachers indicated that the technology was not incorporated into STEM-related subjects in their schools, while 39.1 (n = 106) stated that the technology was incorporated into STEM-related subjects in their schools (as shown in Table 4). Most of the teachers 96.3% (n = 261) revealed that there were no certified STEM teachers in their schools, whereas [3.7%, n = 10) revealed that there were certified STEM teachers in their schools (as shown in Table 4). Consequently, 72.7% (n = 197) of the teachers assured that there were no Professional Development Opportunities (PDO) given to reinforce their knowledge and pedagogy in the STEM field. From Table 4, the majority of the teachers [65.3% (n = 177)] highlighted that students in their schools were not involved in Career and Technical Education (CTE).

Conferring from Table 5, there is a considerable difference between teachers who mentioned that there were no dedicated STEM laboratories in their school and teachers who indicated that there were dedicated STEM laboratories in their schools ($p < 0.05$). There is also a significant difference between teachers who indicated that the technology was not incorporated into STEM-related subjects and teachers who stated that the technology was incorporated into STEM-related subjects in their schools ($p < 0.05$). Furthermore, there is also a significance between teacher respondents who indicated that there were no certified STEM teachers in their school and teachers who indicated that there were certified STEM teachers in their schools ($p < 0.05$). Additionally, the teachers who indicated that there were no professional development opportunities given to augment their pedagogy in STEM and teachers who stated that there were professional development opportunities to reinforce their knowledge in STEM vary significantly ($p < 0.05$). Referring to Table 5, there is a considerable difference between teachers who highlighted that students in their schools were not involved in Career and Technical Education and teachers who highlighted that students in their schools were involved in Career and Technical Education ($p < 0.05$).

4. Discussion

4.1. *Gender*

The study revealed gender disparities among teachers teaching STEM-related subjects in the selected study areas. The issue of gender was only restricted to students, as confirmed in the studies by Refs. [12–20] which established that more males are participating in various STEM-related courses than females. However, conferring from Tables 4 and it extends to the teaching profession. Gender is one of the issues that has gained attention within the educational setting. Equity in education and classroom instruction implies that both males and females should be given equal opportunities to succeed. The fourth and fifth Sustainable Development Goal (SDG) extensively focuses on bridging the gender disparity that has existed in various facets of life. This includes eradicating discrimination of all forms against females, gender violence and early-age marriage, promoting inclusive participation of women in decision-making, and equal opportunities for educational success. These are geared towards heightening gender equality, and women or girls' empowerment [21].

Of course, there has been an exponential increase in the number of females in STEM fields [22], despite this increase, men continue to be more dominant than women, especially at the upper levels of professions as seen in this study. Recently in Ghana, males and females pursued STEM courses in approximately equal numbers, resulting in as many girls as boys completing Senior High School equipped with the knowledge to pursue STEM majors in higher education. However, fewer women than men pursue these majors. Studies have established that the observed dominance is commonly due to embracing assumptions about attributes associated with being male or female. This is an increasingly sensitive situation that stems from local culture and traditions. For instance, in some Ghanaian cultures, there has been a notion that women are made for the "kitchen" and hence anything contrary to this assertion is regarded unacceptable. Individuals also learn the "so-called" characteristics and behaviours associated with males and females from their society, friends, media, religious organizations, institutions, and family [18], leading to a series of gender-related stereotypes.

As reported by Ref. [21], less than 25% of STEM degrees in Ghana were earned by women. Factors contributing to this observed dominance in STEM-related majors in the Ghanaian setting as established by Ref. [23] include stereotypic thinking, uncertainty about gender policy guidelines in the education sector, a lack of understanding of the importance of STEM, gender insensitivity during instruction, insufficient funding by the gender units of Ghana Education Service (GES), and limited cross-sectoral collaboration among the various government agencies and ministries in promoting the education of girls. Other factors influencing the observed dominance include those linked to the individual, such as self-confidence, career indecision, a limited number of women STEM role models, locus of control, and limited job prospects in STEM, as well as those associated with the family, such as the socioeconomic status of the parents and school-related factors such as subject structure, interest, and preference [17].

4.2. Teachers' familiarity, connection, and awareness of STEM curriculum and standards

The study also showed that teachers in the selected study area were familiar with STEM education and had a connection with STEM education. This finding of the study is in agreement with studies by Refs. [24,25]. However, this is in contrast with studies by Refs. [11,26] which revealed that teachers were not familiar with STEM education prior to integration in their respective study areas. Indeed, understanding teachers' familiarity and connections can help facilitate the implementation and success of STEM practices. In Ghana, various centres of higher education still consider the traditional subjects of Biology, Chemistry, Physics, Integrated Science, Information Communication Technology, and Mathematics as the channels through which students can pursue STEM programmes in universities. This has resulted in most teachers lacking the prerequisites needed to effectively implement STEM-related learning experiences.

Additionally, the study also revealed that teachers in the selected study areas were not familiar with the STEM curriculum and the various standards. This conforms with studies by Refs. [11,26] which showed that teachers were not familiar with the STEM curriculum and standards prior to implementation. It is worth noting that STEM field curricula and standards are foundational procedures and experiences that allow students to deepen their understanding of the connections that exist between science, technology, engineering, and mathematics. These curricula and standards include; Common Core State Standards (the Standards for Mathematical Practice) [CCSSM], Next Generation Science Standards (NGSS), and International Society for Technology in Education Standards for Technology (ISTE).

It can therefore be speculated that the reason for the familiarity and connection may be due to teachers' professional learning experiences as each of the teachers had acquired professional training to either teach Integrated Science, Mathematics, Biology, Physics, Chemistry, or Information Communication Technology. This study suggests that regular teacher capacity building, making available STEM guidelines and nationwide sensitisation to STEM should be given to teachers to augment their STEM familiarization and connection. These will equip them with the knowledge and competencies needed to ensure that they fine-tune their instructional pedagogy to match the outlined principles of STEM education.

4.3. Integration and instructional time

The study revealed that STEM education has not been integrated as a somewhat additional course, which is in agreement with [11,27–29]. There was also adequate time for teaching science as a result of STEM education as opposed to findings by Refs. [11,27–29]. The world has become increasingly diverse and digitalized, as a result, education has also been replete with a series of modifications, knowledge, and philosophies. All these are geared towards ensuring that schools become safe places for imparting knowledge aligned with the 21st-century skills needed to match the increasing trends of globalization. This includes developing a competency that rightly equips students with relevant experiences that modify their independence, understanding, confidence, and discovery, thereby complementing their ability to explore concepts, ideas, and issues that have local and global significance. These foundations have prompted the need for the integration of STEM curriculums and standards, pedagogical processes, and STEM instruction. Moreover, the amount of instructional time needs to be made available. Ample resources are needed for successful STEM integration, including time and place for cooperation, time for planning, and technological tools. Teachers must collaborate across disciplines with colleagues when delivering STEM lessons.

This will go a long way to reinforce students' domain of natural curiosity, gathering and organizing information, consideration of and acceptance of varying opinions, synthesis of learned concepts, and reflective thinking [30]. With these competencies, learners will keenly appreciate learning and this devotion to learning will be maintained throughout their lives [31]. The integration process of STEM may challenge teachers to modify their instructional philosophy to embrace STEM teaching and learning approaches. These teaching-learning approaches aligned with STEM education include project-based learning, problem-based learning, the design-based instructional approach, the 7 E instructional model, computer-based learning, flipped learning, blended instruction, scaffolding, technology-enhanced learning, hands-on learning, and evidence-based learning [32]. Additionally, the integration process may also challenge teachers to embrace student-centred instruction, diversity and inclusivity, and modern forms of assessment such as authentic assessment.

4.4. STEM laboratory and technology in STEM-related subjects

The study also revealed the absence of STEM-dedicated laboratories and technology to facilitate STEM-related activities. These findings agree with the ones by Refs. [3,11,27–29,33]. A possible influence of this observation is funding and limited support from the central government. For students to pursue STEM and embrace a coherent STEM experience, infrastructure must be made available [34]. These infrastructures include schools, clubs, museums, laboratories, youth programs, and STEM curricula [3]. The majority of laboratories in the chosen study area were only for the subject domains they covered (Biology, Physics, Chemistry, and Information Communication Technology), not for interdisciplinary teaching purposes, as the existing curriculum was specifically designed for individual subject domains.

It is essential to acknowledge that learning occurs in three primary domains: cognitive, affective, and psychomotor [35]. If learning occurs within these domains, then instructional procedures should necessarily be aimed at each of these domains. The three domains are explicit to ensure that practices complement the overall learning behaviour of students. Undoubtedly, STEM instruction involves seeing, handling, manipulating, and interacting with models. The knowledge students construct during STEM instruction would be inept unless they observe the process and understand the relationship between action and reaction. To effectively reinforce students' understanding of concepts, teachers have to go the extra mile to provide instructional interventions and innovations that go beyond face-to-face and conventional classroom teaching. The STEM-dedicated laboratory offers an opportunity for students to have first-hand experience in the observation and manipulation of materials to augment their understanding and appreciation of concepts.

Additionally, as computers, cloud programming, and mobile devices become more important, teachers and students have to understand how these devices can be merged into instructional processes to augment students' technological literacy. Technology in education presents numerous advantages. Some of these include designing lesson plans, enhancing virtual simulations, administering assessment items, and making the activity centre lively [36]. These enable students to develop concrete understanding through the assimilation of knowledge and therefore, improve their learning outcomes. Moreover, the use of technologies such as Sakai, Zoom, Automation, Artificial Intelligence, Mixed Reality (MR), Augmented Reality (AR), and Virtual Reality ensure that students are fully participating in a classroom task [37]. The study recommends that since there are pre-existing laboratories in the selected study areas, policymakers and educational stakeholders should provide comprehensive in-service training, capacity-building workshops and conferences, and professional development programs to adjust or reinforce teachers' pedagogy to use the available materials to complement STEM teaching. Moreover, some preexisting laboratories in some schools have outlived their usefulness. A case can be made for Amantin Senior High School, Jema Senior High School, and Prang Senior High School. Educational policymakers and other stakeholders should consider constructing ultra-modern STEM-dedicated laboratories for these schools and other schools whose laboratories have outlived their usefulness.

4.5. Certification and professional development opportunities (PDO)

The study also revealed the absence of certified STEM teachers and limited Professional Development Opportunities. The finding agrees with the studies by Refs. [11,28] that showed that most schools lacked certified STEM teachers and there were limited opportunities for professional development. Studies by Ref. [38] highlighted the importance of teacher certification and professional development opportunities in the successful integration of STEM education. Given that, there is a lack of STEM-dedicated resources and technology, and no defined or formal STEM curriculum and standards, there is a need for innovative ways to enhance interdisciplinary STEM instruction.

Professional Development Opportunities are a continuous process used by teachers not only to maintain but also to enhance and broaden their professional knowledge, values, and abilities [39]. The National Teaching Council (NTC) of Ghana created the teachers' professional development framework in Ghana, which formalizes a teacher's commitment to being a professionally competent and relevant practitioner. Of course, STEM in education is both a curriculum and pedagogy [29]. Pedagogy defines the teacher's responsibilities within the STEM classroom. The teacher directs students to analyse problems from different facets by questioning. These ensure that students will have many opportunities to engage in the learning process by integrating their intellectual, emotional, and spiritual intelligence with everyday life situations [40]. All this is achieved through certification and professional development for teachers. Hence, teachers must take critical consideration of the STEM content and update their knowledge and skills with the advanced trends in pedagogical practices for effective STEM teaching. This study suggests that the National Teaching Council (NTC) of Ghana should endeavour to regularly provide teachers with professional development programs and in-service training, conferences on STEM education for teachers to examine how STEM might be included in the curriculum while concentrating on improving teachers' content expertise and STEM experiences. Moreover, there should be a comprehensive preservice education that will ensure that STEM as a program of study is incorporated into various universities and colleges of education to train teachers who are well vested to teach STEM. Effective professional development.

4.6. Students' involvement in career and technical education (CTE)

The study also revealed an inadequate opportunity for students to enrol in career and technical education programs. In the past ten years, career technical education (CTE) has evolved as a research-backed strategy to increase participation in various disciplines and give students access to a wide range of job options. According to studies on CTE participation, students who enrol in at least three CTE programs complete more challenging coursework, enrol in more advanced STEM courses, and are more likely to pursue and complete bachelor's degrees, and are less likely to drop out of high school [41].

As previously stated, STEM in education is both a curriculum and a pedagogy [29]. The curriculum comprises cross-curricular practical challenges for students to solve. Consistent with [42], the assimilation of knowledge in STEM programs has to be categorical both within disciplines and throughout the disciplines. Students must have premeditated instruction in the connectedness of science, technology, engineering, and mathematics [29]. There are numerous forms of this process, but they all comprise a cyclical process of students appraising their solutions and then working to develop them. Students use hands-on activities, experiential models, and practical applications of content to solve their challenges. These cyclical processes are often in the form of Career and Technical Education (CTE) challenges where students are given the platform to apply various concepts to context. It could be speculated that the reason for this observation was due to funding from the central government, which agrees with the studies by Refs. [41,43]. This study therefore recommends that teachers should be equipped with technical and vocational aligned with the subjects. This will foster the dissemination of these competencies to students to complement the limited opportunities given to students to enroll in Career and Technical Education (CTE).

5. Conclusion and recommendation

To achieve a certain educational goal, policymakers and other educational stakeholders should make available appropriate measures to achieve it. The study ascertained the factors that compromise the integration of STEM practices in studied Public Senior High and Vocational-Technical Schools all in the Bono East Region of Ghana. The findings revealed a disparity in gender among teachers teaching STEM-related subjects in the selected study areas. To bridge this gap, this study recommends that government initiatives such as the construction of STEM senior high schools for girls, the construction of STEM clinics, and various sensitisation exercises on women empowerment should be made nationwide, and not centralise these good initiatives in certain regions. Moreover, the Girls' Education Unit of the Ghana Education Service, religious organizations, and instrumental civil societies should consider organizing STEM seminars, workshops, conferences, and capacity-building symposiums for girls not only in various senior high schools but basic schools.

The study also revealed that teachers in the selected study area are familiar with STEM education and have a connection with STEM education. However, this may be due to teachers' professional learning experiences as each of the teachers had acquired professional training to teach Integrated Science, Mathematics, Biology, Physics, Chemistry, or Information Communication Technology. Furthermore, the findings of the study showed that the general integration and implementation of STEM practices throughout the studied Senior High Schools were below the mark. Further, STEM has not been introduced in the all of selected schools. These observations were because of inadequate STEM teaching-learning materials, limited certified STEM teachers, lack of STEM-dedicated infrastructure, motivation in the form of professional development opportunities, limited access to STEM documented standards and curriculum, limited technological incorporation, and limited time for teaching STEM-related subjects.

To change the situation, the study recommends that educational policymakers and stakeholders introduce different initiatives including policy reforms, adoption of a STEM framework (presented in Fig. 1), new curriculum, modernization of existing STEM infrastructure, building new STEM dedicated infrastructure, and the provision of modern technologies to STEM-related schools. Additionally, teachers should also be given all-inclusive STEM training. STEM education challenges teachers to be knowledgeable and skilful. Hence, training programs, short courses, and training workshops could help teachers develop their knowledge about STEM

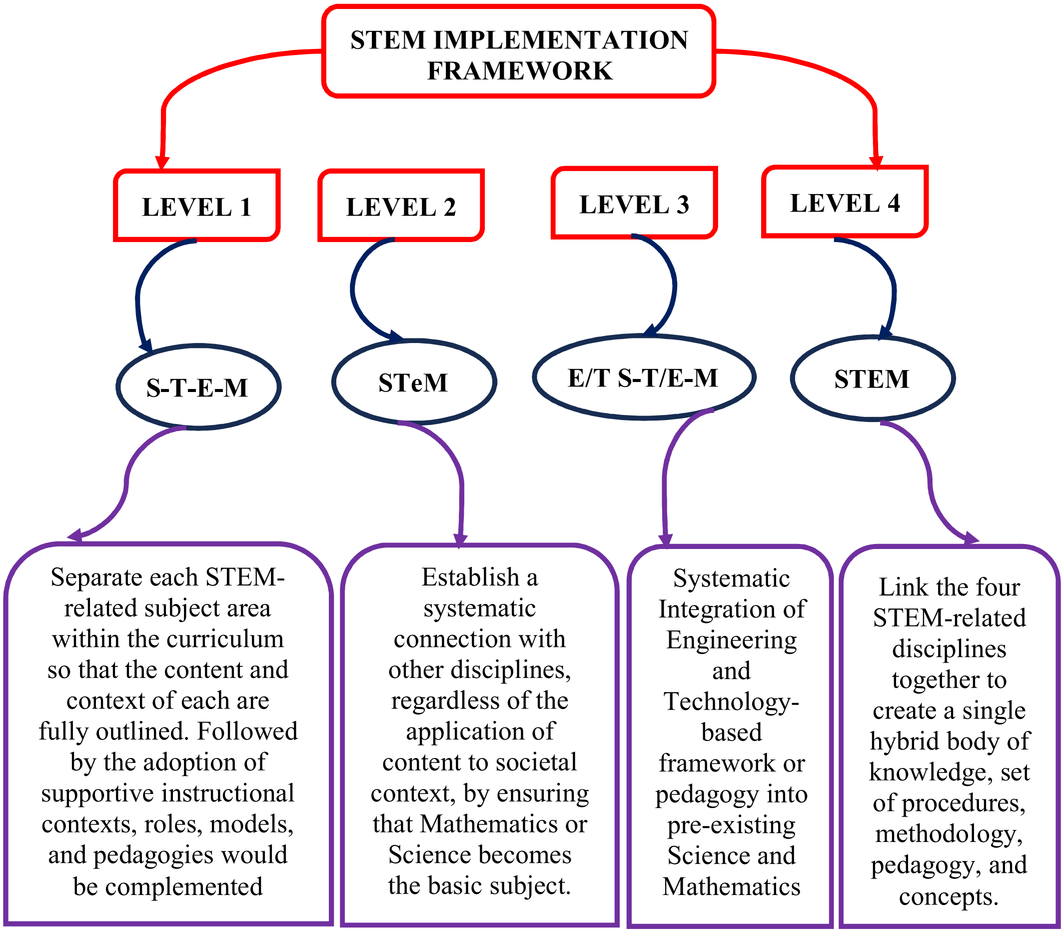

Fig. 1. A framework of STEM Integration adopted from Mpofu [44].

content and the skills to teach this content. STEM teaching requires creativity to be able to convert content into applications, hence, teachers must be inspired to attend courses and training. Moreover, teachers can prepare to teach STEM by understanding students in the domain of natural curiosity, gathering and organizing information, consideration of and acceptance of varying opinions, synthesis of learned concepts, and reflective thinking. This recommendation will provide teachers with the skills necessary to conduct an investigation and foster independence in teaching STEM.

Besides, teachers must embrace the paradigm shift from a teacher-centred to a student-centred approach to education. A renowned progressivist, John Dewey, emphasized that effective teaching could only occur when students determine largely what is to be learned, with the teacher acting as a guide but not a leader in the learning process. Teachers might face the challenge of students' disengagement due to the complexity and abstract nature of STEM education [45]. However, with a student-centred educational approach and the incorporation of constructivist learning approaches, teachers can increase students' curiosity, creativity, and motivation. Finally, provisions should be made for teachers to attend STEM educational conferences both locally and internationally as this would help them grow on the job. A proper combination of these can bring about the required progress in STEM practice.

5.1. A recommended STEM integration framework that could be adopted

In addition to these changes, this study strongly recommends, among others, that there should be a comprehensive policy regarding STEM integration. This is because STEM education initiatives may require substantial shifts or changes in pedagogy, curriculum, and assessment. The integration process could begin by considering the framework or model presented in Fig. 1. The framework entails an interconnected level, where each has a strong collaborative connection to link the four STEM disciplines together. Details of concepts at each level are described below.

5.2. Level 1 (S-T-E-M)

Level 1 (as shown in Fig. 1) is the separatist approach, abbreviated *S*-T-E-M, with the hyphens between the letters symbolising the interrelationship that involves the teachings of STEM subjects [44]. The separatist approach's historic identity includes both its history and philosophy of topic specificity as well as that of its distinct fields. Policies that seek to increase the number of STEM subjects, courses, or academic programmes in educational institutions can be used to infer the existing employment of this strategy [44]. This level involves holistically incorporating the various STEM-related fields into the school curricula. In Ghana, since there exist traditional science and mathematics curricula, the integration could be done by introducing engineering and technology aspects into the already existing curriculum.

5.3. Level 2 (STeM)

At this level, the emphasis is on teaching Science and Mathematics while also forging linkages between the two fields of study. This level is based on the idea that making connections between and within the two STEM-related domains positively correlates with the number of subjects involved [44]. Mathematics is not only the foundational language for all other knowledge disciplines; it is also a network of theoretical and practical subfields that interact with one another. This improves how effectively mathematics links to and mediates between different scientific disciplines. This establishes the tone for how science, technology, engineering, and mathematics are used in "real-life" applications. A teacher's knowledge of teaching mathematics and a science subject is necessary for this technique to be implemented successfully, much like at level 1 [44].

5.4. Level 3 (E/T S-t/E-M)

This level describes the systematic incorporation of either Engineering or Technology into preexisting Science and Mathematics disciplines [44]. This brings about combinations such as Science-Engineering (*S*-E), Science-Technology (*S*-T), Technology-Mathematics (T-M), or Mathematics-Engineering (M-E). This combination is based on the assertion that engineering or technological reasoning, decision-making and practices can be integrated into science or mathematics.

5.5. Level 4 (STEM)

This level illustrates the integration of all four STEM-related subjects into a single, all-encompassing, or cogent teaching and learning paradigm. Interdisciplinary integration's primary goal is to remove the conventional paradigm boundaries that exist between the four science disciplines (Biology, Chemistry, Physics, and Mathematics) and to advance STEM. By fusing the study of academic science, technology, engineering, and math principles with lessons from the real world, teachers are supposed to assist students in making connections between their academic environment, their local community, their place of employment, and the global economy.

5.6. Study's limitation

Despite the contributions mentioned above, the study has several drawbacks that call for additional studies. The study employed a descriptive survey research design which may limit the generalization of the study's findings. Also, since the questions in the data collection instrument were closed-ended and not as detailed as desired, teachers were unable to express further concerns regarding the implementation of STEM practices in their respective schools. Furthermore, an online survey was used to obtain the data. Some teachers were unable to reply to the survey because of concerns about poor internet connectivity and the high cost of internet bundles. In this regard, 271 teachers responded to the questionnaire. Additionally, although the study proposes strategies to enhance the effective integration and implementation of STEM practices, it fails to provide targeted support for students while resolving different barriers. Based on it, the authors proposed that the study be repeated using a series of data collection methods (quantitative and qualitative) and data collection instruments which may provide more clear insight into teachers' perspectives on the implementation of STEM educational practices. Despite these limitations, our study satisfies the current gap in research on the factors hindering the implementation of STEM practices in the Bono East Region of Ghana.

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Data availability statement

The data are available and can be given out upon written request.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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