EVALUATING THE EFFECTIVENESS OF STEM TRAINING PROGRAMMES IN GHANA

BY

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DECLARATION BY STUDENT

I hereby declare that this research is a result of my own original research and that, no part of it has been presented for another degree in this university or any other higher education institute. I further declare that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

STEPHANIE KEKELI HORSU MADC23006 …………… 12th December 2024 …………………

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DECLARATION BY SUPERVISOR

This Project Work has been prepared and presented under my supervision according to the guidelines for supervision and formatting of Project Work laid down by the Institute of Journalism under the University of Media, Arts and Communication (UniMAC-IJ)

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ABSTRACT

This study aimed to evaluate the effectiveness, challenges, and sustainability of STEM training programs in Ghana. The research employed a quantitative cross-sectional survey design to gather data from 282 participants, including 260 university students and 22 corporate trainers. Simple random sampling was used to select students, while convenience sampling was employed for trainers. Data were collected using structured questionnaires and analyzed with IBM SPSS software, utilizing descriptive statistical techniques. The findings revealed that 46% of trainers rated the programs as highly effective, while 27% viewed them as moderately effective and 18% as limited in impact. Similarly, 85% of students expressed willingness to recommend the programs, reflecting positive individual experiences. Major challenges identified included technological limitations (40% of trainers) and insufficient practical learning resources (25%), which hindered hands-on skill development. Structural and financial barriers, such as inconsistent resource allocation, further constrained program delivery. Promising sustainability efforts were observed, with 55% of trainers engaged in initiatives to ensure program longevity and 91% collaborating with external stakeholders to enhance resource availability. Pre- and post-tests were the most commonly used evaluation method (55%), though diversifying assessment techniques was recommended. Recommendations include enhancing technological infrastructure, providing practical resources, addressing financial barriers, and strengthening sustainability through partnerships and diverse funding models. This study highlights the need for systemic improvements and offers actionable insights to enhance STEM training programs in Ghana. Future research should focus on longitudinal impacts, gender dynamics, and stakeholder collaboration to further inform educational policy and practice.

Keywords: STEM, STEM Training, STEM Education, Evaluation, Sustainability, Effectiveness, Impact, Collaboration, Corporate Organization, Curriculum, Reliability, Skills.

DEDICATION

This work is dedicated to my family and my husband Mr Joshua Worlasi Amlanu.

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I extend my deepest appreciation to the numerous individuals who played instrumental roles in the successful completion of this work.

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LIST OF ABBREVIATIONS

STEM	Science Technology Engineering Mathematics
CSR	Corporate Social Responsibility
OECD	Organization for Economic Co-operation and Development
UNESCO	United Nations Educational Scientific and Cultural Organization
TPACK	Technological Pedagogical Content Knowledge
AIMS	African Institute for Mathematical Sciences
SHS	Senior High School
IFC	International Finance Corporation
MoFEP	Ministry of Finance and Economic Planning
KIC	Kosmos Innovation Center
NBSSI	National Board for Small Scale Industries
SME	Small Medium Enterprises
TVET	Technical Vocational Education Training
ICT	Information Communication Technology

CHAPTER ONE

INTRODUCTION

1.0 Background to the Study

In today's rapidly evolving technological landscape, proficiency in Science, Technology, Engineering, and Mathematics (STEM) disciplines has become a crucial driver for the development of individuals, organizations, and nations as a whole. Scholars have emphasized the value of STEM education in developing critical thinking, problem-solving, and analytical skills, which are essential for success in various fields (Hrabowski 2019). The National Science Foundation (2020) affirms this by arguing that STEM education prepares students for the 21st-century workforce, where problem-solving and adaptability are highly valued. Similarly, Bardoe et al. (2023) argue that STEM-based knowledge and skills dominate the global economy and as a result, have gained massive global acceptance.

The African Union’s Agenda 2063 recognizes the strategic role STEM education plays in accelerating Africa’s development, stating that converting the continent’s youth dividend into a highly skilled STEM workforce by 2050 can be a game-changer (African Union, 2015). This push is driving countries across the continent to ensure that their human capital base is equipped with the requisite STEM skills to stay competitive. It is in line with this that African countries like South Africa, Kenya, Rwanda, Nigeria, Morocco and Ghana among others have put at their forefront the promotion and strengthening of STEM education and training.

In South Africa, the government has made significant strides in promoting STEM education through initiatives such as the National Development Plan 2030 (National Planning Commission, 2012). The country has also established specialized STEM schools such as the Oppenheimer Memorial Trust (OMT) schools to provide advanced STEM education to learners from underprivileged communities (Oppenheimer Memorial Trust, 2021).

Kenya has also placed strong emphasis on STEM education with programs like STEM Education project improving the quality of STEM teaching and learning at Secondary Schools (World Bank, 2019). The government also launched initiatives like the "Sheza" program to promote girls' participation in STEM, fields (AIMS, n.d.).

Rwanda launched the "Miss Geek" competition to encourage girls' participation in STEM alongside its Regional Centre of Excellence in Biomedical Engineering and eHealth (CEBE) program to offer specialized training in biomedical engineering and boost STEM education (UNESCO, 2017).

Nigeria has recognized the importance of STEM education for its rapidly growing economy and has launched initiatives like the STEM Education Fund, which provides funding for STEM-related programs (Federal Ministry of Education, Nigeria, 2021). The country has also established specialized STEM centres, such as the National Biotechnology Development Agency (NABDA) Bioresources Development Centre (NABDA, n.d.).

Similarly, Ghana has made significant strides in advancing STEM education. The country has implemented National STEM Education Policy to improve STEM teaching and learning at all levels of education (Ministry of Education, Ghana, 2020). The country has invested over GHS 700 million in research and book allowances, established twenty (20) STEM centres and opened ten (10) new model STEM schools, with 7 (seven) currently operational. Ghana has also launched initiatives like the Girls in ICT program to bridge the national gender gap in ICT and female participation in STEM fields (UNESCO, 2019).

A report by the International Finance Corporation (IFC) projects that there will be over 230 million digital jobs in Sub-Saharan Africa by 2030 with Ghana alone offering 9 million of these jobs. Meeting this demand will require the providing 20 million training opportunities to citizens by 2030 (IFC, 2019). However, the National Budget Statement of the Ministry of Finance and Economic Planning (MoFEP) in 2021 revealed that Ghana's economy faces challenges in competing globally in the STEM domain, and as a result, must take the necessary steps to ensure that it becomes a major STEM education hub (Bardoe et al. 2023).

The IFC report also advocates for educational providers to partner with technology companies to expand their portfolios as part of efforts in contributing to the United Nations Sustainable Development Goal 4; Quality Education (IFC, 2019). It against this backdrop that corporate organizations, as part of their Corporate Social Responsibility (CSR) initiatives, embark on STEM trainings to compliment government's STEM education efforts with the aim of boosting the digital skills capacity of citizens.

Some of these STEM training programs include;

MasterCard Foundation Scholars Program: The Mastercard Foundation Scholars Program at the African Institute for Mathematical Sciences (AIMS) Ghana is an initiative that seeks to engage students in Junior and Senior High Schools to debunk misconceptions surrounding Mathematics and STEM education. Scholars from the program, comprising 33 individuals from 10 African countries, visit these schools and utilize various teaching methods, including games, to showcase the practical applications of Mathematics and inspire students to embrace these subjects and pursue careers in STEM-related fields (Zeleza, 2019).

Robotic Workshops and Competitions: These initiatives focus on promoting robotics education and engaging students in hands-on STEM activities. It organizes workshops, camps, and competitions that allow students to design, build, and program robots. Participants learn about robotics principles, programming, and engineering concepts through practical projects and challenges (Mensah, 2019).

Girls Can Code: This initiative specifically targets young women, aiming to bridge the gender gap in STEM fields. It offers coding and digital skills training programs tailored to the needs and interests of female participants. The curriculum covers various programming languages, web development, mobile app development, and other technological skills. The program also provides mentorship and career guidance to encourage more women to pursue STEM careers (Kwakye, 2021).

Huawei Digital Skills Training: Offering digital skills (STEM) training to Senior high school girls at rural areas in courses like Cyber Security and Privacy Protection, Data Storage and Transfer and Coding across various educational institutions. This initiative is aimed at bridging the digital literacy gap and empowering them to improve their prospects with digital skills (Graphic Online, 2022).

MTN Bright Scholarship and ICT Training: This program offers scholarships and ICT training programs to deserving students pursuing STEM-related degrees. Additionally, the ICT training component equips students with practical skills in areas such as software development, cybersecurity, data analysis, and networking through hands-on training and industry-relevant projects (Quartey, 2020).

NBSSI Entrepreneurship and Technology Training: The National Board for Small Scale Industries (NBSSI) provides entrepreneurship and technology training programs to support small and medium enterprises (SMEs) in Ghana. These programs include workshops on technology adoption, digital marketing, and entrepreneurship skills development. Participants learn how to leverage technology to enhance their business operations, reach new markets, and stay competitive in the digital age (Quartey, 2020).

Tullow Educate to Innovate Program: Tullow Ghana as part of its socio-economic policy has established the Pre-Tertiary STEM Programme, also known as 'Educate to Innovate with STEM'. The programme supports 2000 students from 10 senior high schools in Ghana's Western Region with after-school, mentorship and teaching support to equip and prepare students for their science exams, and encouraging them to choose sciences at the second cycle level right through to university (Tullow Oil, 2022).

Despite the proliferation of STEM training programs in Ghana, there is a lack of research evaluating their effectiveness, with reference to its sustainability, long-term impact and influence on students' educational and career choices.

1.1 Problem Statement

Science Technology Engineering and Mathematics (STEM) education has played a crucial role in developing a skilled workforce while fostering innovation which are essential drivers of economic growth and global competitiveness (Charette, 2013). Recognizing its importance of STEM education, the Government of Ghana, in collaboration with the Ministry of Education, Ghana

Education Service, and other stakeholders, have invested significantly in improving its quality, particularly at the Senior High School level. A study by Bardoe et al. (2023) reveals that GHS 674.6 million has been spent in enhancing teaching and learning of STEM across the country.

Ghana's focus on STEM education is driven by the need to prepare its workforce for the demands of the 21st-century economy, address societal challenges, and position the nation as a competitive player in the global marketplace. STEM skills are increasingly vital for industries such as agriculture, healthcare, energy, and information technology, which are key sectors for Ghana's development agenda. To complement the effort of government, various corporate organizations have developed initiatives to promote the interest of students in STEM fields particularly among those in rural communities, to help bridge the digital divide. However, despite these investments made by corporate organizations in STEM, there is a lack of effective evaluation mechanisms to assess the impact of these training programs (Asante, 2019). This gap makes it challenging to determine whether these initiatives are successfully equipping participants with the necessary skills, knowledge, and competencies to excel in STEM-related fields and contribute to the nation's development goals.

It is in line with this that the study seeks to evaluate the effectiveness of STEM training programs implemented by corporate organizations in Ghana. As Caffarella and Daffron (2013) emphasize, "Evaluation provides data that can be used to enhance programs and ensure they are meeting the needs of learners and stakeholders". By evaluating these STEM training programs, this study aims to generate insight that will inform decision-making regarding program improvements and sustainability. Furthermore, the findings will contribute to the broader understanding of the effectiveness of corporate-sponsored STEM initiatives in Ghana, guiding future efforts to promote STEM education and training in the country.

1.2 General Objective

The general objective of this study is to evaluate the effectiveness of STEM training programmes in Ghana with specific references to training by corporate organizations in the country.

1.3 Specific Objectives

The specific objective of this research is to:

i. To assess the impact of STEM training programs on participants' knowledge, skills, and attitudes towards STEM fields.

ii. To identify the challenges and barriers faced by STEM training programs in Ghana.

iii. To explore the sustainability measures in place for STEM training programs and their long-term viability and determine the level of collaboration among stakeholders (government, organizations, academic institutions) in implementing STEM training programs.

1.4 Research Questions

i. What has been the impact of STEM Training programs on participants' knowledge, skills and attitudes towards the STEM fields?

ii. What are the challenges faced by STEM training programs in Ghana?

iii. What sustaining measures have been put in place to enhance the long-term viability of STEM training programs and the level of collaboration among stakeholders (government, academic institutions) in implementing STEM training programs?

1.5 Significance of the Study

STEM education is crucial for fostering innovation, economic growth, and global competitiveness. This study will provide insights into the effectiveness of STEM training programs in Ghana by corporate institutions which can inform policies and strategies that will have long-term impact on beneficiaries with appropriate measures adopted to enhance its sustainability.

In Ghana, organizations and stakeholders invest significant resources in STEM training programs. This study will provide valuable feedback on the effectiveness of these investments, which can guide future resource allocation and decision-making processes.

Finally, by identifying lapses, challenges, barriers, and best practices, this study can offer recommendations to improve the design, delivery, and implementation of STEM training programs, ensuring they achieve their intended outcomes more effectively.

1.6 Scope of the Study

In enhancing the relevance and timeliness of the findings, the study will focus on STEM training programs implemented by corporate organizations within the past 2-4 years.

It will assess the following aspects of the program; sustainability measures, participant outcomes (impact on their skills, know and career choices), and stakeholder collaborations.

With reference to the target participants, the study will engage university students, to inquire whether the courses they are pursuing now have any relation with STEM training programs they engaged in at senior high school level.

1.7 Organization of the Study

The study will be organized into the following chapters:

Chapter 1: Introduction will provide an overview of the research, including the background, problem statement, research objectives, research questions, significance of the study, scope, and organization of the study.

Chapter 2: Literature Review will present a comprehensive review of relevant literature on STEM education, the importance of STEM training programs, challenges in STEM education, and the effectiveness of STEM initiatives in Ghana and other countries. It will also discuss theoretical frameworks related to program evaluation and effectiveness.

Chapter 3: Research Methodology will describe the research design, approach, data collection methods, sampling techniques, data analysis procedures, and ethical considerations.

Chapter 4: Data Analysis and Findings will present the analysis of the collected data, including descriptive statistics, and any other relevant analytical techniques. The findings will be organized according to the research objectives and questions.

Chapter 5: Summary, Conclusions and Recommendations will summarize the main conclusions drawn from the study and provide recommendations for enhancing the effectiveness of STEM training programs in Ghana. It will also outline suggestions for future research in this area. It will include References, which will list all the sources cited in the study, adhering to the appropriate referencing style (e.g., APA,) and Appendices which will include supplementary materials, such as survey instruments, data collection tools, and any other relevant supporting documents.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

This chapter examines the theoretical and conceptual foundation for evaluating the effectiveness of STEM training programs sponsored by corporate organizations in Ghana. The review focuses on the System Theory as the primary framework, complemented by Kirkpatrick's four model and the Sustainability Theory in comprehensively assessing the effectiveness of STEM training programs. The combination allows for a holistic evaluation that considers both psychological aspects of learning and practical outcomes. Empirical review is also presented in this chapter as well as the lessons learnt from the empirical studies.

2.1 Theoretical Review

2.1.1 Theories of Training and Training effectiveness

Different learning theories are reflected in the design and implementation of different training and development events. The implications for training and development are captured by the Systems Theory (Katz & Kahn, 1996), Kirkpatrick's Theory (1994) and Sustainability Theory of evaluating training effectiveness and long-term sustainability.

2.1.2 The Systems Theory

The systems theory may be defined as a group of interrelated and interdependent parts of processes operating in sequence, according to a predetermined plan, to achieve a goal or series of goals (Bryan, 1990).

A training system is therefore a set of parts coordinated to accomplish the goal of helping individuals gain competence in the present or future work through the acquisition and development of appropriate skills, knowledge and attitudes. Like any other open system, it consists of four main elements: inputs from the environment, a conversion process, output and feedback (Dixon, 1996). From Holcomb's (1993) perspective, trainees form the basic input together with other resources such as physical facilities, reading materials and resource persons. The design and conduct of the training programme constitute the process and the trainees are the output. The evaluation of the training course is the feedback on the basis of which the training may be judged as effective or ineffective, and, where necessary, improvements are made in subsequent courses.

When applied to corporate-sponsored STEM training programs in Ghana, the system's objective might be to enhance STEM skills among SHS students and potentially create a pipeline of future STEM professionals. Inputs would include SHS students, corporate trainers, curriculum, and resources such as computer equipment. The output would be students with improved STEM skills and awareness, while feedback would involve measuring the program's effectiveness against predetermined standards. For example, a STEM training program sponsored by a multinational technology company in Ghana might have the following components:

Inputs: SHS students from selected schools, corporate STEM professionals as trainers, and specially designed curriculum.

Process: A series of weekend workshops over a school term, focusing on coding, data protection and privacy protection, robotics, and data analysis.

Outputs: Students with enhanced STEM skills, increased interest in STEM careers, and completed projects.

Feedback: Pre and post-training assessments, student feedback, teacher observations, and long-term tracking of participants' academic choices.

Figari (1994) posits that a systems approach to training encompasses the entire environment in which the training occurs, including the identification of training needs and other crucial elements such as establishing training objectives, designing and implementing the training program, and evaluating its effectiveness. When applied to corporate-sponsored STEM training programs in Ghana, this approach considers the current landscape of STEM education in Ghanaian Senior High Schools (SHS), the sponsoring corporations' objectives, and national educational priorities (McMahon & Carter, 1990). For example, the Ministry of Education of Ghana has established a goal to enhance STEM skills among SHS students nationwide. This governmental initiative has significantly shaped the development and execution of corporate-sponsored STEM programs. These programs are now being tailored to align closely with the Ministry's focus, ensuring that corporate efforts complement and reinforce national educational strategies.

Casio (2019) notes that improper assessment can lead to training that is irrelevant to actual requirements. This can instigate a situation where training given has no relevance to the actual requirements of the participants’ needs. The design of the training programme depends on its objectives as well as the level of competencies of requirement of the participants and the nature of learning they are expected to acquire. Unless the training objectives are clear, no purposeful evaluation is possible as evaluation can be done only in terms of the predetermined objectives. Noel et al., (2017) affirm this by indicating that the design of corporate-sponsored STEM training programs should depend on clear objectives and the required competencies of participants.

According to Cole (2002), a systems approach to training follows a logical sequence of networked activities commencing with the establishment of a policy and the resources to sustain it. This is sequentially followed by an assessment of training needs, specifying training objectives, specifying target population who should be trained, designing training programme, implementing training and evaluating. Evaluation of corporate-sponsored STEM training programs in Ghana is essential for continuous improvement and demonstrating impact. This evaluation should be done in terms of predetermined objectives (Armstrong & Taylor, 2020). For instance, if a program aims to increase the number of SHS students choosing STEM subjects for their tertiary education, evaluation metrics might include the percentage of participants who select STEM courses in university applications.

2.1.3 Limitations of the Systems Theory

While the Systems Theory provides a comprehensive framework for evaluating STEM training programs, it is not without limitations. One potential challenge is the complexity of the educational environment in Ghana, which may make it difficult to isolate the effects of corporate-sponsored programs from other factors influencing students' STEM skills and interests. Additionally, the long-term nature of some desired outcomes (such as career choices) may pose challenges for timely evaluation and program adjustment.

2.1.4 Kirkpatrick's Four-Level Evaluation Models

To complement the Systems Theory and address some of its limitations, Kirkpatrick's Four-Level Model offers a structured approach to evaluating STEM training programs in Ghana (Kirkpatrick & Kirkpatrick, 2006). This model provides a comprehensive framework for assessing educational, training and learning program outcomes ranging from immediate reactions to long-term impacts. According to the model, evaluation should always begin with level one and move sequentially through the subsequent levels. The four levels are:

Reaction: Measures of Participant Satisfaction and Engagement

Level 1 assesses the initial reaction of the trainees to the training programme (Kirkpatrick, 1994). It evaluates participants' immediate satisfaction with the program content, delivery methods, and overall experience, usually through questionnaires, surveys and focus group discussions. Rajeev, Madan and Jayarajan, (2009) attest that Level 1 employs attitude questionnaires to measure the trainee's perceptions, administered after the program or after each session of it. For STEM programs this could include a survey rating their enjoyment of the activities, clarity of instructions, and their interest in future STEM initiatives.

Learning: Assesses the Knowledge and Skill Acquisition

Level 2 evaluates whether the objectives of the programme have been met by measuring skills and knowledge gained (Gordon, 1992). Assessment methods include criterion-referenced tests, pre-tests/post-tests, observation, and interviews. Mishra (2003) emphasizes the importance of combining pre-tests with post-tests to validate knowledge gained. In their absence self-assessment tests can be used although Rajeev et al. (2009) assert that self-evaluation tests are less objective than criterion-referenced tests.

Behaviour: Evaluates the Application of STEM Skills

Level 3 measures the degree to which participants apply their newly acquired knowledge and skills in their academic work and daily lives. It employs both formal methods, such as testing and informal techniques, such as observations, surveys and interviews to evaluate the transfer of learning from the training environment to real-world situations. For example, teachers might observe whether students who participated in a programming workshop are now more likely to use coding to solve problems in their science classes.

Results: Measures the Long-Term Impacts of the Training on Broader Objectives

This level measures the final results of your training which includes broader and long-term impacts on the objectives. In the context of STEM training, it will evaluate the long-term, systemic impacts of the STEM training program on educational outcomes, career trajectories, and the overall STEM landscape in Ghana. It assesses whether the program contributes to achieving larger objectives, such as increasing STEM enrolment in universities or improving gender balance in STEM fields.

2.1.5 Limitations to Kirkpatrick's Model

While Kirkpatrick's model offers a comprehensive framework for evaluating STEM training programs in Ghana, its application may face several challenges. Resource constraints in developing educational systems can make implementing all four levels, especially level 4, costly and time-consuming. The model may require further adaptation to fully align with Ghanaian educational norms and values, ensuring cultural relevance. Long-term tracking of participants' progress over extended periods may prove challenging in the Ghanaian context, particularly due to potential limitations in data collection and management systems. Additionally, isolating the specific impact of STEM programs from other influencing factors can be difficult, potentially complicating the attribution of long-term outcomes solely to the training interventions.

2.1.6 Sustainability Theory

The Sustainability Theory, as proposed by Bossel (1999), adds a crucial dimension to the evaluation of STEM training programs in Ghana by emphasizing the long-term viability and impact of interventions. This theory complements the Systems Theory and Kirkpatrick's Model by focusing on the enduring effects of training initiatives beyond their immediate implementation. In the context of corporate-sponsored STEM training programs, the Sustainability Theory provides a framework for assessing the lasting impact of these initiatives on the country's educational landscape and workforce development. It encourages evaluators to look beyond short-term outcomes and consider how these programs contribute to the sustainable development of STEM education and careers in Ghana.

One key aspect of sustainability in STEM training programs is the continued engagement of students with STEM subjects beyond the duration of the program. Laal and Salamati (2012) argue that sustainable learning initiatives should foster a lifelong interest in the subject matter. For instance, a corporate-sponsored robotics program might be evaluated not just on immediate learning outcomes, but also on how it influences participants' subject choices in secondary school and university, as well as their extracurricular STEM activities.

Another important consideration is the integration of program elements into regular school curricula. Sustainable STEM training programs should aim to leave a lasting impact on the educational system. As Tilbury (2011) notes, education for sustainable development requires systemic changes in teaching and learning. In the Ghanaian context, this might involve assessing how techniques or technologies introduced in corporate-sponsored programs are subsequently adopted by schools. The development of local capacity to continue STEM training without ongoing corporate support is another crucial aspect of sustainability. Fadeeva and Mochizuki (2010) emphasize the importance of building local expertise and resources for long-term sustainability. A sustainable STEM program might, for instance, include a "train the trainer" component where Ghanaian educators are equipped to continue the program independently. The long-term impact on STEM career choices and Ghana's STEM workforce is perhaps the most significant indicator of a program's sustainability. As Arora et al. (2020) point out, sustainable STEM education should ultimately contribute to national development goals. Evaluators might track program participants over several years to assess their educational and career trajectories. For example, a longitudinal study might examine whether students who participated in a corporate-sponsored STEM program are more likely to pursue STEM degrees and careers compared to their peers.

2.1.7 Challenges of Sustainability Theory

Evaluating sustainability presents its own challenges such as issues with long-term tracking of outcomes which require significant resources and commitment. Mayne (2001) notes that, attributing long-term impacts solely to specific training programs can be difficult, given the varied factors that influence educational and career choices.

2.1.8 Strengths of the Sustainability Theory

Despite these challenges, incorporating the Sustainability Theory into the evaluation of STEM training programs in Ghana provides valuable insights into their lasting impact. By considering sustainability alongside the Systems Theory and Kirkpatrick's Model, evaluators can develop a more comprehensive understanding of program effectiveness. This holistic approach not only assesses immediate learning outcomes but also examines how these programs contribute to the sustainable development of STEM education and careers in Ghana.

2.1.9 The Synergy between Systems Theory, Kirkpatrick's Four Model & Sustainability Theory

The Systems Theory, Kirkpatrick's Four-Level Evaluation Model, and the Sustainability Theory, when used together, create a robust framework for evaluating training programs across various fields. The Systems Theory provides a comprehensive view of the training process, considering inputs, processes, outputs, and feedback. However, it lacks specificity in measuring individual outcomes. Kirkpatrick's Model provides a structured approach to evaluating specific aspects of training effectiveness from immediate reactions to long-term behavioural changes. This detailed, level-by-level analysis compensates for the broader perspective of the Systems Theory, ensuring both macro and micro aspects are assessed.

Each theory's strengths effectively compensate for the others' weaknesses. While Kirkpatrick's Model excels at measuring immediate to medium-term outcomes, it may fall short in capturing long-term, systemic impacts. The Sustainability Theory fills this gap by focusing on enduring effects and integration into broader systems. It extends the evaluation timeframe, considering factors like continued engagement, curriculum integration, and capacity development.

The Systems Theory ensures that all aspects of the training process are considered, from resource allocation to feedback mechanisms. Kirkpatrick's Model provides a clear structure for measuring outcomes at various levels, from participant satisfaction to organizational results. By leveraging the complementary strengths of these theories, evaluators can develop a comprehensive understanding of training effectiveness that spans from immediate reactions to long-term, systemic impacts, providing valuable insights for continuous improvement and strategic decision-making in training program design and implementation.

2.2 Review of Concepts

2.2.1 The Concept of Training

In the ever-evolving landscape of professional development, training stands out as a cornerstone for individual growth and organizational success. According to Goldstein and Ford (2002), training is "the systematic acquisition of skills, rules, concepts, or attitudes that result in improved performance in another environment”. It encapsulates a structured process designed to bridge the gap between current capabilities and desired performance levels. Building on this foundation, Cole (2002) emphasizes that training should be directed towards the acquisition of specific knowledge and skills for the purpose of an occupation or task. By engaging in training, individuals can enhance their competence and performance, ultimately contributing to their success in their chosen fields.

The implementation of training has evolved significantly, moving beyond traditional classroom-based instruction. Noe (2020) highlights the integration of technology through e-learning platforms, virtual reality simulations, and blended learning approaches which enable more flexible and personalized learning experiences. This evolution as Salas et al. (2012) argue, reflects the changing nature of work itself, where adaptability and continuous learning have become paramount.

Stone (2000) positions training as having a complementary role in accelerating learning, advocating for its use in situations that require a more directed, expert-led approaches. This perspective underscores the importance of targeted and focused training interventions that address specific needs and gaps in knowledge or skills.

Armstrong (2006) further develops this concept by characterizing training as the use of systematic and planned instruction activities to promote learning, introducing the concept of “learning-based training." Building on this systematic view, Grossman and Salas (2011) propose a comprehensive model emphasizing needs assessment, design, delivery, and evaluation as crucial components for ensuring effective training transfer to the workplace.

2.2.1.1 The Training Process

Training is a crucial process that requires careful planning and execution typically following a systematic approach with interconnected steps that contribute to overall program effectiveness (Beardwell & Holden, 1993; Gordon, 1991; Rajeev et al., 2009). This comprehensive process encompasses several key stages designed to maximize learning and organizational development.

Training policies and resources: Training policies serve as fundamental guidelines for that ensure efficient resources allocation and equal training opportunities. Armstrong (1996) emphasizes that these training policies reflect an organization's philosophy towards employee development and underscore the importance placed on continuous learning and skills enhancement.

Determination of training needs: The needs assessment stage involves a multi-level analysis of organizational, functional, and individual levels. (Cole, 2002) suggests examining performance gaps and conducting surveys, to identify areas where training can make a significant impact. Researchers like Teskey (2005) recommend focusing on variances between success and failure while Fullard (2006) advocates for individual analysis through interviews, observations, and performance records.

Establishing training objectives and training plan: Following needs analysis, clear training is established to define specific learner outcomes. Tamkin and Yarnall (2002) stress the importance of integrating training objectives with performance and reward management. Jones, George and Hill (2000) outline a comprehensive planning process that includes developing detailed lesson plans, selecting appropriate methods, and preparing trainers.

Implementation of training plan: This critical stage involves designing specific training lessons, selecting appropriate training methods, and preparing qualified trainers. Each training session requires a meticulously crafted lesson plan with content outlines, activities, and time allocations. Chambers (2005) emphasizes the significance of selecting and preparing personnel capable of executing training objectives.

Evaluation and Feedback: The final stage assesses the training program's effectiveness in meeting its objectives, providing crucial insights for future improvements. This step ensures continuous refinement of training approaches and validates the investment in human capital development.

In conclusion, the training process is a systematic approach that involves careful planning, needs assessment, objective setting, and implementation. Each step in this process is crucial for ensuring effective and purposeful training outcomes.

2.2.1.2 The Benefits of Training

Training plays a crucial role in personal and professional development, offering numerous advantages across various contexts. As highlighted by Ajibade (1993) and Arikewuyo (1999), it serves as a valuable avenue for acquiring new knowledge and skills.

Obisi (1996) emphasizes that training prepares individuals for achievement and overall development, equipping them with the necessary competencies to perform tasks efficiently. This preparation extends beyond specific job requirements, contributing to broader personal growth. From an organizational perspective, Cole (2002) notes that training can significantly enhance operational efficiency. By reducing errors, minimizing equipment misuse, and mitigating risks, it often leads to cost savings and improved resource utilization.

Oguntimehin (2001) points out that it also helps develop a range of competencies, including, technical, human and managerial skills for the furtherance of individual and organizational goals. It also plays a vital role in change management, fostering adaptability and resilience in the face of new challenges. Training offers intangible benefits as well. Rajeev, Madan, and Jayarajan (2009) observe that it can provide recognition and opportunities for career advancement, contributing to personal satisfaction and achievement.

In today's competitive environment, Swist (2002) identifies training as a key factor in maintaining a competitive edge. By keeping individuals and organizations current with industry advancements, it promotes innovation and excellence. In essence, training is a multifaceted tool that enhances skills, boosts efficiency, facilitates change adaptation, and drives both individual and organizational growth. Its value as a catalyst for improvement and advancement remains consistent across various domains.

2.2.2 The Concept of Evaluation

Evaluation is a systematic method for collecting, analysing, and using information to assess the effectiveness and efficiency of projects, policies, and programs. Learning Point Associates (2010) emphasizes that evaluation aims to answer critical questions about the intended impact of initiatives for stakeholders in both public and private sectors. The notion of answering questions about efficiency and effectiveness connotes a feedback loop from the evaluator to the posers of the questions.

Ryan and Cousins (2009) highlight that the primary goal of evaluation is to provide useful feedback to various audiences, including sponsors, donors, administrators, and other constituencies. The ultimate objective is to influence decision-making and policy formulation through empirically-driven insights. However, the impact of evaluation is not always immediate, as findings may have delayed influence when more conducive conditions arise.

The OECD (2006) notes a consistent purpose across institutions: assessing the effectiveness or efficiency of programs, projects, training methods, and policies. Nicol and Macfarlane (2006) define evaluation as determining the extent to which program objectives are realized through programmed activities.

Scheerens, Cees and Thomas (2003) distinguish that evaluation itself is a process of reasonably assessing and drawing conclusions about a program, rather than prescribing its goals. This approach requires careful consideration of key interconnected concepts:

Reliability: Reliability focuses on the consistency of measurement. Kalleghan and Stufflebearn (2003) describe it as the ability to reproduce the same results using identical methods, regardless of the evaluator. Rossi et al. (2004) emphasize that reliable measures provide more statistically powerful and credible findings.

Validity: Validity centres on the suitability of evaluation techniques for their intended purpose. Potter (2006) defines it as the extent to which an instrument measures what it is supposed to measure. Ryan and Cousins (2009) note that validity can be subjective, often determined by stakeholder acceptance.

Sensitivity: Rossi et al. (2004) stress that evaluation instruments must be sensitive enough to detect potential changes in the program's impact. An insensitive instrument may obscure the program's true effects by including irrelevant or inappropriately designed measurement items.

Evaluation process: Program evaluation may be conducted at several stages during a program's lifetime. Each of these stages raises different questions to be answered by the evaluator, and correspondingly different evaluation approaches are needed. Rossi et al. (2004) suggest the five kinds of assessment, which may be appropriate at different stages. The five assessments are the assessment of the need for the program, assessment of program design and logic/theory, assessment of the program's cost and efficiency, assessment of how the program is being implemented, and assessment of the program's outcome or impact or what it has actually achieved.

In conclusion, evaluation is a complex, multi-dimensional process that requires rigorous methodological approaches to provide meaningful insights into program effectiveness and potential improvements.

2.2.3 Conceptualization of STEM Education and STEM Training

The relationship between STEM education and STEM training is characterized by a nuanced, interconnected nature, with subtle distinctions and significant overlap in their fundamental objectives and approaches.

2.2.3.1Definition of STEM Education

Breiner et al. (2012) define STEM education as "the study of science, technology, engineering, and mathematics disciplines, with an emphasis on integration across these four fields for in-depth exploration of STEM pathways." This definition underscores the interdisciplinary essence of STEM education, highlighting the importance of holistic knowledge acquisition and cross-disciplinary understanding. Key characteristics of STEM education include:

¶ Broad foundational knowledge acquisition

¶ Interdisciplinary approach

¶ Comprehensive exploration of scientific and technological concepts

¶ Emphasis on theoretical understanding

2.2.3.2 Definition of STEM Training

STEM training is distinguished by its focus on practical applications and skill development. Kloser et al. (2021) provide a comprehensive definition, describing it as "educational experiences that incorporate practices, concepts, and skills from two or more STEM disciplines in an integrated, real-world context." Distinctive features of STEM training include:

- ¶ Practical skill development
- ¶ Real-world application of knowledge
- ¶ Hands-on learning experiences
- ¶ Flexible learning environments

However, Vennix et al. (2018) maintains that, STEM training is not limited to formal classroom settings but can also include workshops, camps, competitions, and other informal learning environments, providing a broader view while highlighting its flexibility and adaptability to different learning contexts.

2.2.2.3 Relationship between STEM Education and Training

While STEM education and STEM training have distinct emphases, they are mutually reinforcing. Education provides the foundational knowledge, while training focuses on applying that knowledge in practical contexts. This symbiotic relationship ensures that learners not only understand theoretical concepts but can also effectively implement them in real-world scenarios.

The intertwined nature of STEM education and training reflects the dynamic, evolving landscape of scientific and technological learning, emphasizing both theoretical understanding and practical skill development.

2.2.3 Conceptualization of STEM Education and STEM Train

In Ghana, STEM education has witnessed significant growth since the 2000s. The country has recognized the importance of STEM education for developing a skilled workforce and driving economic growth. Like many countries, there have been efforts in recent years to improve STEM teaching and learning at the primary, secondary, and tertiary levels. Recent initiatives include:

The 2015 ICT in Education Policy, emphasizing teacher training in digital skills and introducing ICT as a subject from primary through high school (Ministry of Education Ghana, 2015).

The Education Strategic Plan 2018-2030, prioritizing improved quality of teaching and learning in STEM at all levels ((Ministry of Education, Ghana, 2018).

Plans to build 35 STEM Senior High Schools and 5 STEM-based universities (Ministry of Finance Ghana, 2023).

The establishment of specialized STEM schools, with 7 out of 10 proposed schools already operational (Ghanaweb, 2023).

Investment in Technical and Vocational Education and Training (TVET) with 52,133 final year TVET students participating in the 2024 Certificate II Examination across Ghana compared to 32,402 participants last year (Daily Graphic, 2024. Pg28)

Without pinpointing an exact timeframe, it's reasonable to say that STEM education has gained increasing prominence as a priority area in Ghana over the past 10-15 years, driven by national development plans. However, quantitative data on STEM enrolment and performance remain limited. This low percentage suggests significant room for improvement and underscores the need for increased efforts to promote STEM education and training at all levels.

2.2.4 Role of STEM Education and Training in Enhancing Career Goals of Students

In the contemporary educational landscape, STEM education plays a pivotal role in influencing students' career aspirations and professional trajectories. Multiple research studies have highlighted the complex interplay between educational experiences and career choices, revealing significant insights into how STEM learning impacts student motivations and future career paths (Kayan-Fadlelmula et al., 2022; Sahin et al., 2020; Vooren et al., 2022).

Existing research demonstrates persistent challenges in STEM career engagement, including low college enrolment rates and diminished student interest despite substantial educational investments (Chen et al., 2024). The perception of STEM professionals critically influences students' career intentions, with students more likely to pursue these fields when they view STEM professionals as intelligent, innovative, and successful (Cohen et al., 2021).

Similarly, Gossen and Ivy, (2023) argue that early educational experiences emerge as a fundamental determinant of career aspirations. Primary school interactions and extracurricular STEM activities significantly contribute to building students' confidence and interest in scientific and technological disciplines. A study by Blotnicky et al. (2018) also found a correlation between STEM knowledge and the likelihood of students pursuing STEM careers. Their study, which used a quantitative survey methodology, revealed that students with high mathematics self-efficacy (MSE) and STEM knowledge were more likely to choose STEM careers. These studies collectively highlight the crucial role of STEM education and training in shaping students' career aspirations. They suggest providing early exposure to diverse STEM career opportunities, developing students' scientific and mathematical confidence, integrating informal learning experiences, and offering comprehensive career information. These strategies can potentially transform students' perceptions and inspire greater participation in STEM fields.

However, a notable research gap exists, with most studies predominantly focusing on Western educational contexts. This limitation underscores the need for more comprehensive research in developing countries like Ghana, where understanding local educational dynamics is crucial for tailoring effective STEM career development strategies.

In conclusion, STEM education serves as a powerful catalyst in shaping students' career goals by providing knowledge, building confidence, and fostering genuine interest in scientific and technological domains. Strategic, holistic approaches that recognize the multifaceted nature of career aspiration development are essential for nurturing the next generation of STEM professionals.

2.2.5 Corporate Involvement in STEM Training in Ghana

Corporations worldwide are increasingly investing in STEM training to address skills gaps and drive innovation. A study by PwC (2019) found that 79% of global CEOs are concerned about key skill availability, with international companies like IBM and Google launching targeted training initiatives to bridge this gap. While these global initiatives demonstrate the potential of corporate involvement in STEM training, their effectiveness and applicability in different cultural contexts require further investigation.

In Africa, corporate STEM programs have gained significant momentum. South Africa's Sasol Inzalo Foundation has reached over 100,000 beneficiaries, while in Ghana, collaborative efforts between government and industry partners have emerged, such as training 100,000 girls in STEM-related courses. However, a systematic review by Amankwah et al. (2022) found that while corporate STEM programs in Africa have shown promise in increasing STEM skills and interest, there is a lack of rigorous evaluation studies.

Some notable corporate STEM training initiatives which needs rigorous evaluation in Ghana include:

- ¶ MTN Ghana's Digital Skills Training Program, which claims to have trained over 5,000 youth in coding and digital skills since 2018 (MTN Ghana, 2021).
- ¶ Kosmos Energy's Innovation Centre, providing entrepreneurship and STEM skills training to Ghanaian youth (Kosmos Energy, 2020).
- ¶ Tullow Educate to Innovate Program which supports 2000 students in Ghana’s Western Region with after-school, mentorship and teaching to prepare them for science exams, and encourage them to choose sciences at the second cycle level right through to university (Tullow Oil, 2022).
- ¶ Huawei Women in Tech training, in partnership with the Ministry of Communications which has trained over 75,000 Junior and Senior High School Girls across the country (Ministry of Communications and Digitalization, 2023).

While corporate involvement in STEM training in Ghana shows promise, substantial opportunities remain for expanding and systematically evaluating these programs to enhance skills development and career opportunities.

2.2.6 Challenges in Implementing and Evaluating Corporate STEM Training in Ghana

Ghana, like many developing countries, faces significant hurdles in implementing an effective STEM education and training ecosystem. Hebebci et al. (2022) highlight common challenges including infrastructure limitations, deficiencies in qualified teaching personnel, laboratory facilities, and financial resources. These structural constraints are compounded by outdated curricula that struggle to align with rapidly evolving technological and industrial requirements.

UNESCO (2017) also identifies gender disparities and cultural biases as challenges that discourage girls and women from pursuing STEM fields. These social constraints significantly undermine efforts to develop a comprehensive and inclusive STEM workforce. Baah-Boateng (2015) points out the disconnect between educational training programs and industry needs as another fundamental challenge. Many existing programs fail to provide students with practical skills directly relevant to workforce demands, creating a substantial gap between academic preparation and professional requirements while Egyir et al., (2020) emphasis the challenge of ensuring long-term impact beyond initial implementation.

Addressing these challenges requires a holistic, collaborative approach. Broman et al. (2022) emphasize the need for multi-stakeholder engagement, involving government agencies, educational institutions, and industry partners. Cappelli et al. (2019) advocate for robust evaluation methodologies and while Patton (2011) suggests ensuring comprehensive stakeholder involvement throughout program development and implementation for meaningful transformation. These challenges underscore the need for a responsive, adaptive STEM education ecosystem that can effectively prepare Ghanaian students for future workforce challenges while driving national technological innovation and economic development.

2.3 Empirical Review

Several studies have employed diverse approaches to evaluate STEM training programs, each contributing unique perspectives to the field. Abdullah, Samupwa, and Alzaidiyeen (2009) conducted a comprehensive evaluation of teacher training programs in Namibia's Caprivi Region, utilizing a cross-sectional design that incorporated views from teachers, students, and administrative units across 43 schools.

Their methodology was grounded in Kirkpatrick's (1994) four-tier model of training effectiveness, assessing reaction, learning, behaviour, and results. This theoretical framework provided a structured approach to evaluating the multifaceted impacts of the training program.

The Namibian study revealed a modest 9.24% improvement in average student performance following teacher training. However, this effect was lower than anticipated and potentially confounded by external factors such as student self-motivation and after-school tutoring. The researchers employed a mix of quantitative and qualitative assessment tools, including student performance metrics, teacher self-assessments, and stakeholder interviews. While this triangulated approach enhanced the robustness of the findings, the absence of pre-test/post-test data for teachers' knowledge and skills was a limitation to the evaluation methodology.

Focusing specifically on Ghana, Agyei and Voogt (2011) investigated the impact of STEM teacher training on ICT integration in mathematics lessons. Their quasi-experimental design, which incorporates pre- and post-intervention assessments, provides a stronger basis for causal inference than the cross-sectional approach used in the Namibian study. The researchers grounded their work in the Technological Pedagogical Content Knowledge (TPACK) framework and Diffusion of Innovations Theory, offering a nuanced perspective on technology integration in education.

Ameyaw and Okai (2022) contributed valuable insights into the effects of STEM education on student achievement in Ghana through their longitudinal study. By grounding their research in Expectancy-Value Theory and Social Cognitive Career Theory, they provided a robust theoretical framework for understanding both academic outcomes and career aspirations. Their use of standardized test scores, career interest inventories, and longitudinal tracking offers a comprehensive approach to assessing STEM education outcomes.

Despite these valuable contributions, several gaps in the literature persist. There is a notable lack of studies examining the long-term impact of STEM training programs beyond immediate academic outcomes. While some studies have touched on contextual factors, there is a need for more in-depth exploration of how cultural, economic, and social factors influence the effectiveness of STEM training in Ghana specifically.

2.4 Conceptual Framework

The evaluation of training programs is a critical component of ensuring their effectiveness and impact. A well-structured conceptual framework can provide a systematic approach to assessing these programs, guiding the evaluation process and ensuring that all relevant aspects are considered. This study integrates Systems Theory, Kirkpatrick's 4 Models, and Sustainability Theory aligning them with a systematic evaluation process. The framework is grounded in a system thinking approach, recognizing the complex interrelationships between program components, participants, and context.

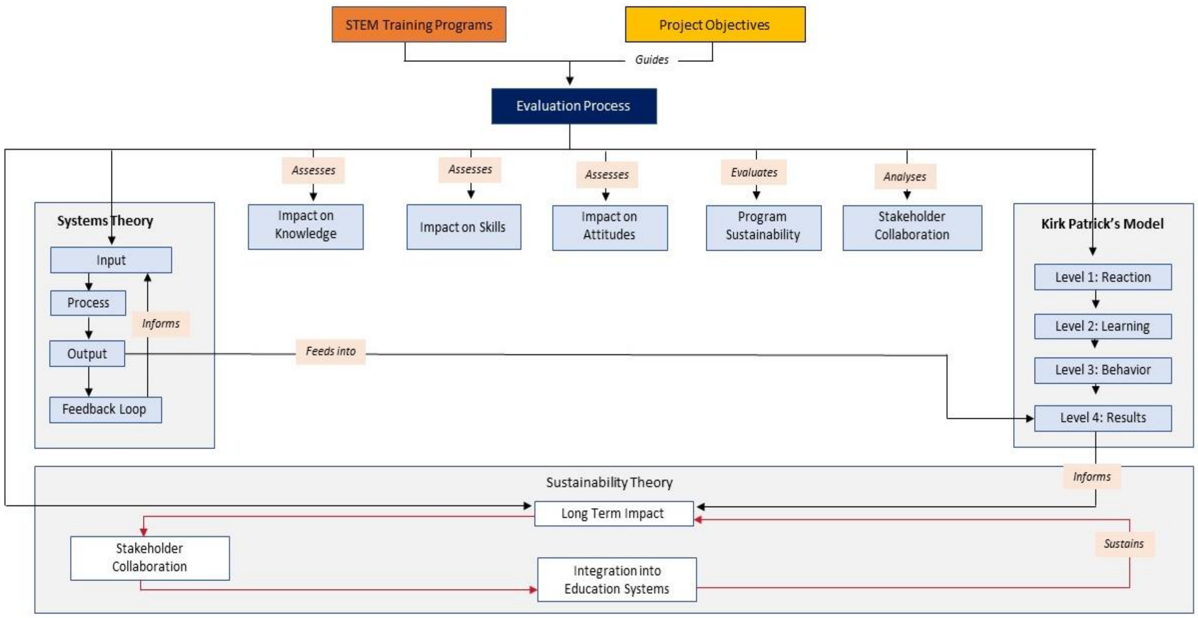

Figure 1: Comparison of Theories

The Systems Theory provides the overall structure, ensuring that all aspects of the program are considered. Kirkpatrick's Model offers a detailed approach to evaluating specific outcomes at different levels, while the Sustainability Theory ensures consideration of long-term impacts and systemic changes.

The Systems Theory conceptualizes the STEM training program as an open system with interconnected components which is Input, Process, Outputs and Delivery. The Inputs involves the resources invested in the program, such as students, corporate trainers, curriculum, and physical resources (Dixon, 1996). The process represents the actual implementation of the training program, including the design and delivery of content (Holcomb, 1993). Whereas outputs represent the immediate results of the training, primarily the students who have completed the program with enhanced STEM skills and knowledge while the feedback is the crucial component which allows for continuous improvement by feeding information back into the system (Cole, 2002).

Nested within the Systems Theory framework is Kirkpatrick's Four-Level Evaluation Model (Kirkpatrick & Kirkpatrick, 2006). This model provides a structured approach to assessing the outcomes of the training at different levels thus, from immediate reactions to long-term impact.

The Sustainability Theory, emphasizes the long-term viability and impact of the STEM training initiatives. It ensures that the evaluation considers not just immediate outcomes, but also the program's potential for creating lasting change in Ghana's STEM education landscape.

The strength of this conceptual framework lies in its integration of robust theoretical foundations with a systematic evaluation process. Each stage of the process corresponds to elements from the theories, ensuring a comprehensive and theoretically grounded assessment of the STEM training program.

By combining these theories and processes, this framework provides a holistic approach to evaluating corporate-sponsored STEM training programs in Ghana and allows for assessment of immediate outcomes, long-term impacts, and systemic changes, while also providing a mechanism for continuous improvement.

2.5 Lessons Learnt

Throughout the literature, it has been emphasized that assessing the effectiveness of training programmes connotes a comparison of the effectiveness before and after the programme. The most appropriate method has been stressed to be a comparison of measures of effectiveness in a pre-test/post-test analysis. However, in the absence of such methods, other tools can be applied in a cross-sectional survey to obtain results of comparative accuracy.

Abdullah et al. (2009) employ a cross-sectional survey to assess the effectiveness of a training programme conducted earlier. It relied heavily on one-point in time individual ratings of changes in teachers' skills, performance, and attitudes toward teaching. Essential lessons to be drawn from the study include the importance of stakeholder participation from the planning through to the implementation and the evaluation stages of the training programme. This is to encourage stakeholders' input as to their actual training needs, the convenience of timing, and to discourage a narrow view on the programme from the perspective of the regulatory body involved in the planning and execution of the programme.

Also, the various studies reviewed made use of diverse theoretical frameworks (e.g., Kirkpatrick's model, TPACK, Social Cognitive Career Theory) which proved valuable. By making use of relevant theories, such as Sustainability Theory, future studies can provide a more comprehensive understanding of the dynamics at play in STEM education.

Finally, it is crucial to acknowledge the importance of involving multiple stakeholders (teachers, students, administrators, corporate partners) in STEM training initiatives as well as their evaluation as highlighted across the various studies.

In conclusion, while existing studies demonstrate the potential positive impact of STEM training programs in Ghana and similar contexts, they also highlight the need for more rigorous, theoretically grounded, and contextually sensitive research. By addressing the identified gaps and employing more diverse and robust methodologies, future research can provide a stronger evidence base to inform STEM education policies and practices in Ghana. This enhanced understanding will be crucial in developing effective, scalable, and sustainable STEM training programs that can drive educational and economic development in the country.

2.6 Chapter Summary

This chapter examines the importance of corporate STEM training initiatives in Ghana's educational landscape including its role in bridging educational gaps and preparing students for future careers in science and technology. As global emphasis on STEM education intensifies, the focus turns to the effectiveness and sustainability of these programs. This chapter proposes a comprehensive theoretical framework combining the Systems Theory, Kirkpatrick's Four-Level Model, and Sustainability Theory, as a robust foundation for evaluating these initiatives.

Empirical evidence suggests that well-designed STEM programs can positively impact student learning and career aspirations. However, their success hinges on integration with existing educational systems, and a focus on long-term sustainability. The review also uncovers significant research gaps, including limited data on the scope and nature of corporate STEM training programs in Ghana, lack of comprehensive evaluations, and insufficient research on long-term impacts.

Evaluation of these training programs is crucial for determining their effectiveness, ensuring relevance to industry needs and educational standards, assessing long-term viability, guiding continuous improvement, and justifying resource allocation. Lessons learned from empirical studies emphasize the need for culturally sensitive approaches, stakeholder collaboration, and seamless integration with existing educational frameworks.

In conclusion, this review underscores the potential of corporate STEM training to contribute significantly to Ghana's technological and economic development. By addressing identified research gaps and applying robust evaluation frameworks, stakeholders can enhance the effectiveness and sustainability of these initiatives.

CHAPTER THREE

METHODOLOGY

3.0 Introduction

This chapter outlines how the research was conducted with emphasis laid on the research design, methods, and procedures employed. The chapter discusses the sampling technique and sampling size of respondents, the data collection instruments and how the data collected from respondents was analysed for this study. Additionally, ethical considerations significant to the research are discussed.

3.1 Research Approach

As Creswell and Creswell (2018) asserts, a research approach encompasses the plan and procedures spanning the steps from broad assumptions to detailed methods of data collection, analysis and interpretation. The importance of selecting an appropriate approach is underscored by Druckman (2005), who emphasizes that researchers must be certain about which method will yield the required information. This means that by using an inappropriate method, the researcher might not achieve the required outcome as the research approach provides the philosophical and methodological foundation guiding the researcher's choices in data collection and analysis, ensuring consistency between research questions, methodology and results.

The study adopted a quantitative research approach to systematically examine the impact, challenges, and sustainability of STEM training programs in Ghana. Quantitative research involves the collection and analysis of numerical data to identify patterns, relationships, and trends

(Creswell, 2014). This approach was deemed appropriate as it allows for objective measurement and statistical analysis of the phenomena under investigation, providing generalizable findings (Taherdoost, 2016).

3.2 Research Design

Yin (2009) argues that research design is the logic that connects the data to be collected and the conclusion to be drawn to the research question in the study. This logical sequence ensures that the empirical data effectively addresses the research questions, maintaining the study's coherence and validity. The study employed a descriptive survey research design**,** which was well-suited for collecting detailed information about respondents' characteristics, behaviours, and opinions. As Creswell (2014) asserts, descriptive research provides a snapshot of a phenomenon at a specific point in time, making it ideal for understanding the perceptions and experiences of STEM program participants. This design allowed for the use of structured questionnaires to gather data systematically, facilitating statistical analysis and interpretation.

3.3 Study Setting and Scope

The research was conducted at universities in Ghana that offer STEM related courses as well as secondary schools within the Greater Accra Region, Ashanti Region and the Eastern Region. These locations were chosen due to their concentration of STEM training programs and their ability to provide access to key stakeholders, including university students, corporate trainers, senior high school heads, and representatives from STEM program implementing organizations.

3.4 Study Population

According to Davies (2007) the term population refers to the category of people about whom you intend to write in your report and from which you plan to draw your sample. The target population for this study will be include;

¶ University students who have participated in the STEM training programs

¶ Corporate-trainers responsible for designing and delivering the STEM training programs

The inclusion of these diverse stakeholder groups aligns with Creswell's (2014) recommendation that researchers should leverage multiple data sources for a comprehensive understanding of the phenomenon under study.

3.5 Sample Size and Sampling Techniques

This study employed a comprehensive sampling approach to investigate STEM training programs in Ghana, encompassing a total of 282 respondents across two distinct groups. The primary sample consisted of 260 university students, with this size determined through Cochran's formula using a 95% confidence level and a 4.3% margin of error, ensuring robust statistical power for analysing student perspectives. The formula is as follows: $n = Z^2 * p * (1-p) / e^2$

Where,

n = sample size

Z = Z-score (1.96 for 95% confidence level)

p = population proportion (0.5 used for maximum sample size)

e = margin of error (0.043 for 4.3%)

Additionally, 22 corporate STEM trainers were included, with this smaller sample size reflecting the practical constraints of accessing corporate professionals for research purposes. While limited, this sample provided valuable insights from the trainer perspective.

The study implemented a dual sampling strategy to capture diverse perspectives effectively. For university students, simple random sampling was employed to ensure equitable selection probability and minimize bias. This approach involved creating a comprehensive list of STEM program participants in Ghana and using a random number generator for selection, thereby enhancing the generalizability of findings (Taherdoost, 2016). In contrast, convenience sampling was utilized for corporate trainers and project coordinators at Senior High schools, acknowledging the practical challenges of accessing these professionals (Etikan et al., 2016). While this non-probability sampling method introduced potential bias, it provided a pragmatic solution for including key informants whose insights were crucial to the research.

This combined sampling approach, as supported by scholars like Lindelof and Taylor (2017), provided a well-reasoned framework for participant selection. The methodology aligned with the study's descriptive design, enabling the collection of comprehensive data from both student and trainer perspectives. The integration of both probability and non-probability sampling techniques, while adhering to established statistical principles for sample size determination, created a balanced approach that addressed both theoretical rigor and practical constraints in educational research.

3.6 Data Collection Instrument

Data for this study was collected based on the research objectives. To gather comprehensive data, this study employed surveys using questionnaires as its main data collection instrument. As defined by Check and Schutt (2012, p.160), a survey involves "the collection of information from a sample of individuals through their responses to questions." This method allowed for the efficient collection of data from a diverse sample.

For the survey, semi-structured questionnaires were used as instruments to collect quantitative data from students and corporate-trainees. The questionnaires made use of close ended questions where respondent chose from a distinct set of responses such as yes or no and from a multiple-choice list. The instrument was pilot-tested with a small group (n=30) to ensure reliability and validity before full deployment.

3.7 Validity and Reliability

To ensure the reliability and validity of the integrated survey instrument, particularly the survey questionnaires, a pilot testing phase was conducted prior to full-scale implementation. This helped to identify and rectify issues with the questions, survey structure, and response options, enhancing the instrument's effectiveness in capturing quantitative data.

3.8 Data Collection Procedure

In view of the ethics in conducting research, consent was sought from the corporate trainers and university students to carry out the study, indicating the number of participants (university students) to be used as sample in the collection of the relevant data and methods to be used. When given the go ahead, questionnaires were then administered to respondents via social media.

3.9 Data Handling and Analysis

Durcevic (2020) defines data analysis as "a process that relies on methods and techniques to taking raw data, mining for insights that are relevant to the business's primary goals, and drilling down into this information to transform metrics, facts, and figures into initiatives for improvement." This process is crucial for extracting useful information from data and making informed decisions based on it.

The quantitative data collected through Likert scales and multiple-choice items were analysed using IBM Statistical Package for the Social Sciences (SPSS) software. This software helped with the coding, analysis and presentation of raw data into meaningful statistics. Descriptive statistics were then generated through SPSS, to paint a broad picture of the findings with inferential statistics also used, where appropriate. These statistical analyses helped identify significant trends, correlations, and potential causal relationships within the data.

3.10 Ethical Issues

Throughout the research process, ethical considerations were given utmost importance to protect the rights and privacy of all respondents. All respondents were provided with detailed information about the study including the purpose, procedures, risks, and benefits of the study and asked to provide informed consent prior to data collection.

Confidentiality was maintained throughout the research process, and respondents were given the right to withdraw at any time. Personal identifiers were removed from the data, with all information collected handled with strict confidentiality. Additionally, the sampling strategy and overall research design were submitted for approval to the appropriate institutional review board prior to implementation.

3.11 Chapter Summary

This chapter has outlined the research methodology employed in the study. The descriptive survey research design, provided a comprehensive understanding of the impact of these programs. Rigorous sampling techniques, data analysis procedures, and ethical considerations have been detailed to ensure the study's validity, reliability, and adherence to research ethics. The proposed methodology is designed to address the research questions effectively and contribute meaningful insights to the field of STEM education in Ghana.

CHAPTER FOUR

FINDINGS AND DISCUSSIONS

4.0 Introduction

This chapter consists of the presentation of findings of the study. The discussion starts with the demographics of respondents with research findings discussed in the second part based on the various research objectives.

4.1 Demographic Data

The demographic characteristics of respondents studied were gender, age, level of education and field years of experience of trainers and students. These were studied in order to provide a background profile of respondents in the study in.

Table 4.1 shows the age range of respondents engaged in the study. Out of 260 respondents, a majority 170 (65%) are aged 22 and above, while a smaller proportion 90 (35%) fall within the 18–21 age bracket.

Table 4.1: Age distribution of students

Age	Frequency	Percent
18-21	90	35
22 and above	170	65
Total	**260**	**100**

Source: Primary data from the field (2024)

This data, based on a sample size of 260 respondents, suggests that STEM training programs in Ghana predominantly attract a more mature audience. This trend may reflect the programmes' alignment with the needs of higher education or career-focused individuals, rather than younger, pre-tertiary respondents.

Table 4.2 shows that the age distribution of STEM trainers involved in evaluating STEM training programs in Ghana is predominantly youthful, with 55% falling within the 18–25 age range.

Table 4.2: Age distribution of trainers

Age	**Frequency**	**Percent**
18 – 25	12	55.0
26 – 35	7	32.0
36 – 45	3	13.0
Total	**22**	100.0

Source: Primary data from the field (2024)

This trend suggests that STEM fields are increasingly attracting younger professionals, reflecting growing interest and accessibility among the youth. Trainers aged 26–35 constitute 30%, representing a significant share of early-to-mid-career individuals. Meanwhile, only 15% of trainers are aged 36–45, indicating relatively lower participation among older professionals.

Figure 2 illustrates the gender distribution of STEM students in Ghana, with males comprising 141 respondents (54%) and females accounting for 119 respondents (46%) out of a total sample of 260.

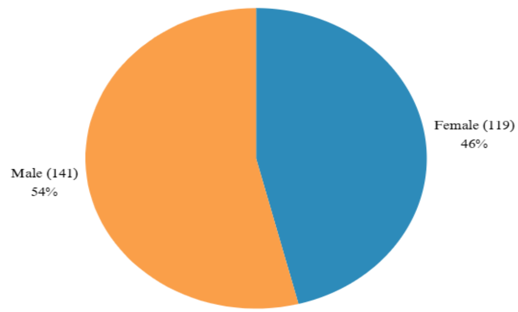

Figure 2: Gender Distribution of Students

Source: Primary data from the field (2024)

This reveals a moderate gender disparity in STEM training programme participation, highlighting ongoing challenges in achieving gender equity in the field. While female participation is relatively substantial, the figures emphasize the need for targeted initiatives to further bridge the gap and promote increased enrolment of women in STEM programmes.

The gender distribution of trainers as illustrated in Figure 3 indicates a balanced representation of male and female respondents. The data showed 50% of the 20 respondents being male and 50% female, demonstrating effective gender inclusivity within the programme.

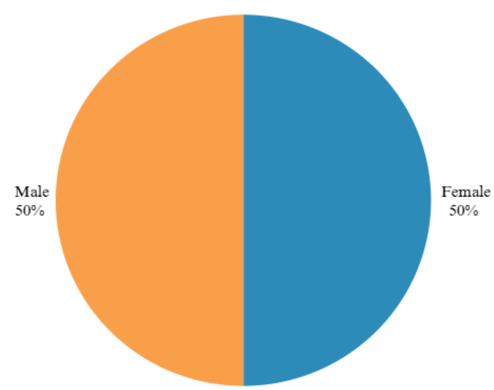

Figure 3: Gender of Distribution of Trainers

Source: Primary data from the field (2024)

These findings are pivotal in evaluating the success of STEM training initiatives in fostering gender equity, a critical metric for sustainable development and empowerment in Ghana's education sector.

The distribution of the highest level of education among STEM trainers in Ghana as shown in Table 4.3 indicates that 68% hold a bachelor's degree, while 32% have a master's degree. This suggests that most STEM trainers possess foundational academic qualifications relevant to their roles, ensuring a solid baseline of expertise for delivering quality STEM education.

Table 4.3: Trainers' level of education

Level of Education of Trainers	Frequency	Percent
Bachelor's degree	15	68
Master's degree	7	32
Total	**22**	100.0

Source: Primary data from the field (2024)

Table 4.4 reveals that the majority of STEM trainers in Ghana (59%) have limited experience, ranging from 0 to 3 years, 18% have 4-6years experience, 14% have 7-19years experience while a smaller segment (9%) boasts extensive experience of 11 years or more.

Table 4.4: Years of experience as STEM trainers

Years of Experience	Frequency	Percent
0-3	13	59
4-6	4	18
7-19	3	14
11+	2	9
Total	**22**	100.0

Source: Primary data from the field (2024)

The data in Table 4.5 reveals a diverse landscape of STEM program engagement, with participation rates ranging from 3% to 21%. Top-performing programs include Girls Can Code (21%), Tullow Educate to Innovate (14%), and Girls in ICT (13%), indicating strong appeal particularly among young women. Mid-tier programs like MTN Bright Scholarship and ICT

Training (10%), GNPC STEM Education Support Program (9%), and The MasterCard Foundation Scholars Program (9%) demonstrate moderate engagement levels.

Table 4.5: STEM training programs students have participated in

Program	Frequency	Percent
ABL STEM Education Support	7	3
Girls Can Code	55	21
Girls In ICT	33	13
GNPC STEM Education Support Program	23	9
Huawei Women in Tech	17	7
Kosmos Innovation Center (KIC) AgriTech Challenge	19	7
MTN Bright Scholarship and ICT Training	27	10
Newmont Ahafo Development Foundation STEM Program	12	5
None	7	3
The MasterCard Foundation Scholars Program	23	9
Tullow Educate to Innovate	37	14
Total	**260**	100.0

Source: Primary data from the field (2024)

These initiatives suggest ongoing efforts to expand technological education opportunities. Programs with lower participation include Huawei Women in Tech (7%), Kosmos Innovation Center AgriTech Challenge (7%), Newmont Ahafo Development Foundation STEM Program (5%), and ABL STEM Education Support (3%). The 3% reporting no participation highlights potential gaps in program awareness or accessibility. The data underscores the need for targeted strategies to improve program visibility, design more inclusive curricula, and address barriers to participation. As emphasized by UNESCO (2023), enhancing STEM educational initiatives requires continuous evaluation and adaptive approaches to maximize student engagement and skill development.

The analysis of STEM training program durations in Ghana as shown in Figure 4 reveals a predominant trend towards short-term, intensive formats, with 71% of respondents engaging in programs lasting less than 4 weeks. Danquah et al. (2021) support this observation, noting that brief training interventions align with resource constraints and targeted skill acquisition strategies in developing educational contexts.

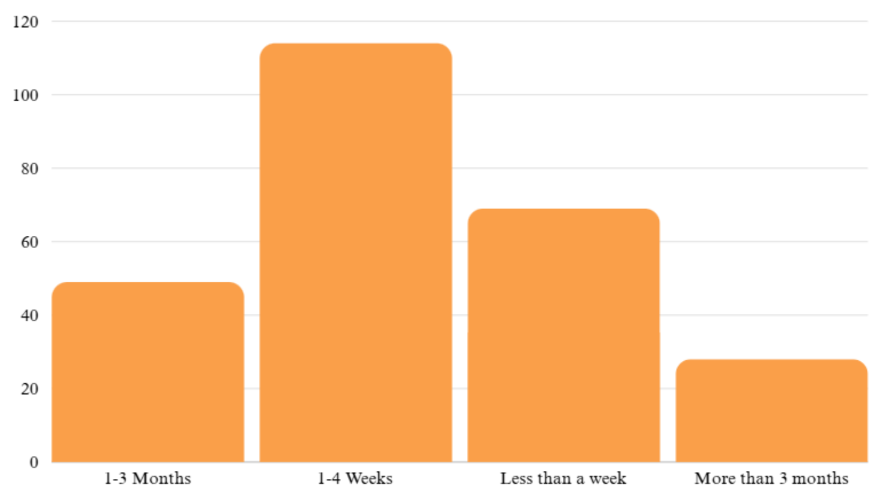

Figure 4: Duration for STEM Training Programs

Source: Primary data from the field (2024)

Corporate trainers similarly in Figure 5 demonstrate a preference for concise formats, with 50% conducting 1-3day workshops, reflecting an approach prioritizing accessibility and immediate skill development.

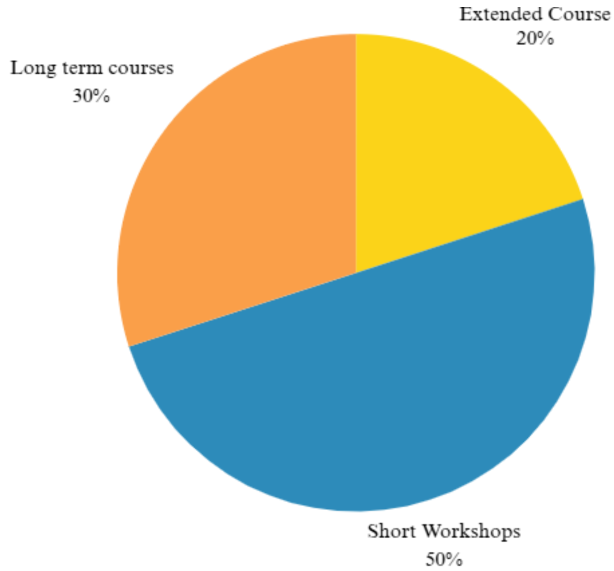

Figure 5: Training Duration

Source: Primary data from the field (2024)

UNESCO's 2023 report on technological education emphasizes the critical need to balance program accessibility with learning depth. While shorter programs may increase participation rates, their effectiveness in delivering comprehensive STEM knowledge remains questionable. The data suggests a nuanced approach is required, potentially incorporating modular training designs that can provide intensive skill development within constrained timeframes while maintaining educational rigor and long-term learning outcomes.

4.2 Research Objective 1: Assessment of the impact of STEM training programs on respondents' knowledge, skills, and attitudes towards STEM fields.

The finding analysed and discussed subsequently helps in ascertaining the impact of STEM training programs on respondents’ knowledge, skills and attitudes towards STEM fields.

The evaluation of STEM training programs in Ghana shows a predominantly positive reception among respondents in areas such as training content, delivery methods, course objectives, and the training environment. According to the data from Table 4.6, out of 260 respondents, a significant majority of 170 (66%) agreed that the programs are relevant, while 16 (6%) disagreed. However, 72 (28%) expressed neutrality, indicating that the programmes did not fully meet their expectations.

4.2.0 Respondents’ Views on Training Content, Delivery Methods, Course Objectives and Training Environment

Table 4.6: Students’ views on the STEM Training Program

Response	Frequency	Percent
Agree	172	66
Neutral	72	28
Disagree	16	6
Total	**260**	100.0

Source: Primary data from the field (2024)

4.2.1 Students' views on whether STEM Training improves their knowledge

The evaluation of STEM training programs reveals a predominantly positive impact on respondents' knowledge. From Table 4.7 a significant majority (62%) of respondents - comprising 38% who agreed and 28% who strongly agreed - indicated that the training effectively improved their STEM subject understanding. This perspective aligns with research by Danquah & Mensah (2022), which suggests these programs effectively meet educational objectives by providing valuable technological skill development opportunities.

Table 4.7: Students' views on whether STEM Training improves their knowledge

Response	Frequency	Percent (%)
Agree	98	38
Strongly Agree	73	28
Neutral	65	25
Disagree	17	7
Strongly Disagree	7	2
Total	260	100

Source: Primary data from the field (2024)

However, the data also highlights areas for improvement. A significant 25% of respondents remained neutral, while 9% expressed dissatisfaction, indicating potential gaps in curriculum design or pedagogical approaches. UNESCO's 2023 report on technological education emphasizes the need for more adaptive and interactive learning methodologies to address these variations in participant engagement and knowledge acquisition.

4.2.2 Students' Perception on Practical Skills Enhancement

Table 4.8 shows a generally positive perception of the effectiveness of STEM training programs in Ghana, with a significant 65% of respondents either agreeing (40%) or strongly agreeing (25%) that the training enhanced their practical skills. However, 25% of students remained neutral, indicating mixed experiences or potential gaps in the training's impact. A smaller percentage expressed dissatisfaction, with 5% disagreeing and another 5% strongly disagreeing.

Table 4.8: ***View on enhancement of practical skills of respondents in STEM fields***

Response	**Frequency**	**Percent (%)**
Agree	105	40
Strongly Agree	65	25
Neutral	66	25
Disagree	12	5
Strongly Disagree	12	5
Total	260	100

Source: Primary data from the field (2024)

These findings suggest that while STEM training programs have been effective for many, there is room for improvement in addressing the needs of a broader audience and ensuring consistent practical skills development.

4.2.3 Perceived Effects of Impact of Training Programs on Technical skills, Problem-solving, Critical Thinking, Digital Literacy, Collaborative Skills, Innovation and Creativity of Respondents

The data in Table 4.9 shows a notably high overall impact, with 217 (84%) respondents reporting significant positive outcomes across technical skills, problem-solving, critical thinking, digital literacy, collaborative skills, innovation, and creativity. While 33 (12%) perceived a low effect and 10 (4%) respondents rated the effect as neutral.

Table 4.9: Perceived Effect of STEM Programmes

Response	**Frequency**	**Percent**
High Effect	217	84
Low Effect	33	12
Neutral	10	4
Total	**260**	**100**

Source: Primary data from the field (2024)

This aligns with research by Freeman et al. (2014) in their meta-analysis of STEM education, which found that active learning approaches significantly improve student performance and engagement in STEM fields.

The data from Table 4.10 illustrates the perceived effectiveness of STEM training programs in Ghana in enhancing technical skills, problem-solving, critical thinking, digital literacy, and collaborative skills among trainers. In examining specific competencies, technical skills development showed robust positive outcomes, with 55% reporting high effects and 41% noting moderate improvements.

Table 4.10: Views of Students on the Perceived Effects of the STEM Program

Effect	High Effects (%)	Moderate Effects (%)	Low Effect (%)
Increased subject knowledge	73	27	-
Critical thinking skills	32	59	9
Problem Solving Skills	45	50	5
Technical skills	55	41	4
Collaboration Skills	41	50	9
Interest in STEM fields	64	36	-
Enhanced Practical Skills	50	45	5
Innovative and Creative	36	55	9
Communication Skills	64	32	4
Team work	59	27	14

Source: Primary data from the field (2024)

This corresponds with research by Watkins and Mazur (2013), which demonstrated that hands-on STEM training significantly enhances technical proficiency. Problem-solving capabilities also demonstrated remarkable strength, with 95% of respondents reporting either high (45%) or moderate (50%) effects. Critical thinking skills development revealed a more nuanced picture, with 32% reporting high effects and 59% noting moderate improvements. This pattern aligns with meta-analyses by Abrami et al. (2015), who found that explicit critical thinking instruction in STEM yields variable but generally positive outcomes. Innovation and creativity outcomes showed promising results, with 91% of respondents reporting positive impacts, while communication skills demonstrated similarly strong outcomes at 96%. These findings parallel research by DeHaan (2009) on fostering creativity in science education and studies by Reynolds et al. (2012) on developing communication skills in STEM contexts.

The relationship between student and trainer perceptions reveals interesting dynamics. While trainers consistently reported higher perceived effectiveness, student responses showed more varied experiences across different competencies. This phenomenon is well-documented by Tanner and Allen (2006), who is explored the "expert-novice gap" in STEM education.

The disparities in perception between trainers and students highlight potential areas for program refinement, particularly in bridging expectations and experiences in critical thinking and collaborative skill development, a challenge also noted by Singer and Smith (2013) in their research on STEM education reform. However, there was a strong alignment between both groups in technical skills and problem-solving capabilities. The consistency between these findings and established research literature suggests that Ghana's STEM training programs are effectively implementing evidence-based practices while facing similar challenges and opportunities for improvement as documented in international STEM education research.

Figure 6. highlighting the varying impacts of STEM training programs on students' academic performance and grades in STEM subjects, with 94 (36%) reporting moderate improvement, 70 (27%) experiencing significant improvement, and 40 (15%) noting very significant enhancement. Combined, these results indicate that 78% of respondents perceived some level of positive impact, reflecting the potential effectiveness of the training programs in enhancing STEM learning

outcomes. However, 43 (17%) indicated slight improvement and 132 (5%) reporting no benefit at all.

4.2.4 Improvement in Student Performance and Grades

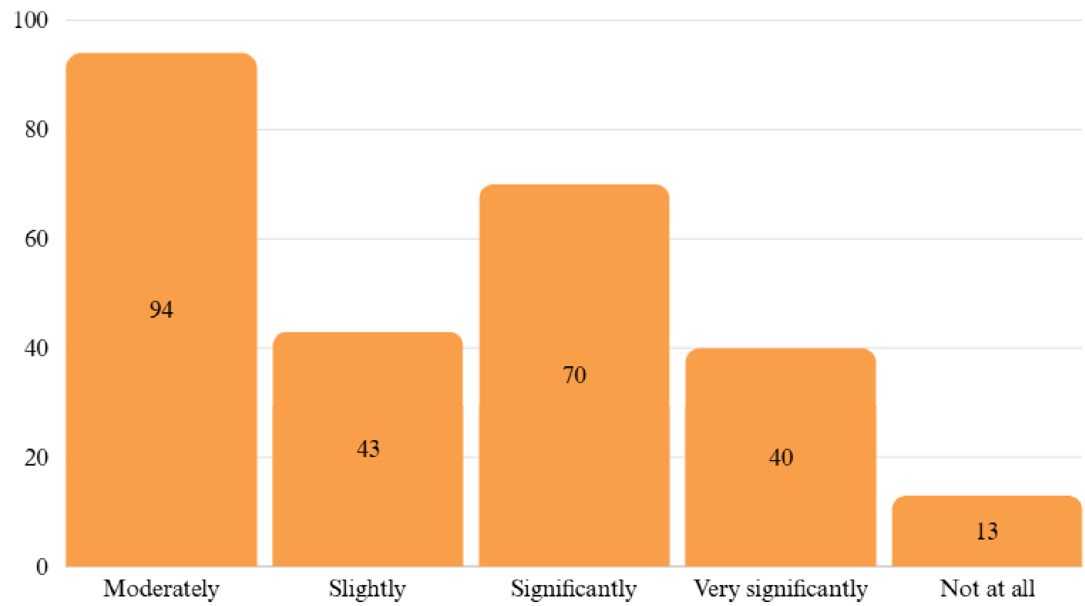

Figure 6: STEM Training Programs Improve Performance and Grades

Source: Primary data from the field (2024)

These findings suggest that while STEM training programs are generally effective in Ghana, there remains room for improvement to ensure more comprehensive and uniform benefits for all respondents.

Figure 7 reveals that 62% of STEM students in Ghana have applied knowledge or skills from their training programs in their regular studies, while 38% have not. This indicates a generally positive impact of STEM training programs in equipping students with relevant competencies that enhance their academic pursuits. However, the significant proportion of students (38%) who have not applied these skills points to potential gaps in the training programs. These gaps may include misalignment between the curriculum and students' academic needs or insufficient opportunities for practical application.

4.2.5 Application of skills gained in regular studies

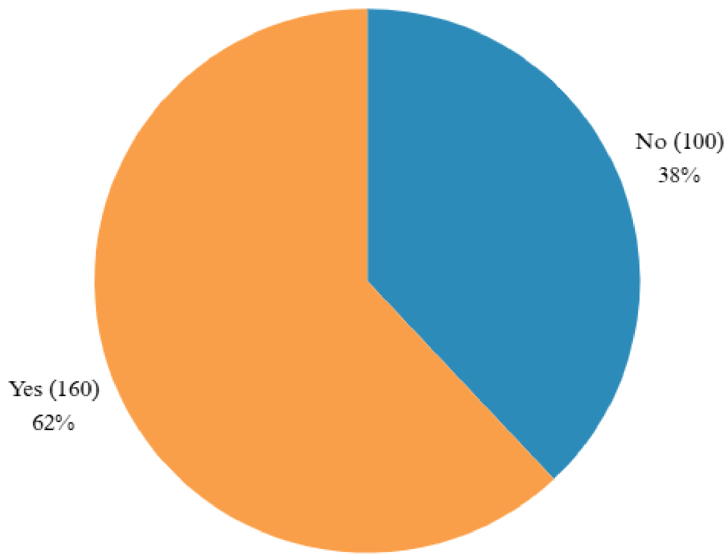

Figure 7: Application of Knowledge from Program

Source: Primary data from the field (2024)

These findings highlight the need for stakeholders to refine STEM curricula, ensuring a more consistent integration of practical and theoretical knowledge to enhance the relevance and effectiveness of the programs in students' academic and career development.

4.2.6 Change Career Interest of Students

The data from table 4.11 indicates that STEM training programs in Ghana have a significant positive impact on students' interest in pursuing STEM careers. 68% of respondents reported an increased interest, while 21% remained unsure and 11% noted no change in their interest.

Table 4.11: STEM program increased the interest in pursuing a STEM career

Response	Frequency	Percent
No	29	11
Not Sure	54	21
Yes	177	68
Total	**260**	**100**

Source: Primary data from the field (2024)

These findings suggest that the programs are effectively inspiring and engaging students, highlighting the importance of targeted interventions in promoting STEM education and encouraging future career paths in these fields. This is further reflected in data gathered from students, on careers they developed interest in after participating in STEM training programs.

Data from Table 4. 12. reveals that after engaging in the training program, 21.6% of respondents expressed an interest in pursuing a career in engineering followed by 18% showing improved interest in programming careers. Roles in data analysis and IT specialist positions each garnered 9.4% interest, while Cybersecurity attracted 6.7%, Data science 5.5%, and Artificial intelligence 2.7%. These findings reflect the growing appeal of technology-driven disciplines.

Table 4.12: Interest in STEM Programs

Interest	**Frequency**	**Percent**
Artificial Intelligence	7	2.7
Biology	5	2
Computer Science	16	6.3
Cybersecurity	17	6.7
Data Analysis	24	9.4
Data Science	14	5.5
Engineering	55	21.6
IT Specialist	24	9.4
Mathematics	6	2.4
Medicine	6	2.4
Networking	5	2.3
Not sure	23	9.0
Programming	50	18.4
Robotics	6	2.4
Total	**260**	**100**

Source: Primary data from the field (2024)

The data demonstrates the programs' success in promoting engagement with a broad range of STEM fields, particularly in high-demand technological and engineering sectors. It also highlights the need for tailored support to further align students' aspirations with industry opportunities.

4.2.7 Influence on Respondents' Choice of Course at University

Table 4.13 also shows that, out of the 260 respondents, 40.4% confirmed that STEM training directly influenced their course choice, indicating that these programs are largely effective in aligning students' academic pathways with STEM-related disciplines. Meanwhile, 30.0% acknowledged partial influence, suggesting that while these programs play a role, other factors may also shape decision-making. 29.6% reported no influence, highlighting a gap in the capacity of STEM programs to fully engage or direct a significant portion of students toward STEM fields at the tertiary level.

Table 4.13: Informed Participant's decision in selecting university courses

Response	**Frequency**	**Percent**
No	77	29.6
Partially	78	30.0
Yes	105	40.4
Total	**260**	**100.0**

Source: Primary data from the field (2024)

These findings emphasize the need for targeted improvements to better guide and inspire students in aligning their university and career choices with STEM pathways.

4.2.8 Overall Perceived Effects Analysis of the training Program

Table 4.14 show that overall, the evaluation of STEM training programs in Ghana has varied perceptions among trainers regarding the programs' effectiveness in achieving their intended objectives. Among the respondents, 10 (46%) believe the programs are effective "to a great extent," indicating strong confidence in their impact. However, 27% rated the effectiveness as "to a moderate extent," while another 18% indicated it was effective "to a small extent," reflecting moderate satisfaction levels. A small minority reported extremes, with 5% finding the programs completely successful and another 5% perceiving them as not effective at all.

Table 4.14: Trainers' views on the extent to which the programs achieve their intended objectives

Response	Frequency	Percent
To a very great extent	1	5
To a great extent	10	46
To a moderate extent	6	27
To a small extent	4	18
Not at all	1	5
Total	**22**	**100**

Source: Primary data from the field (2024)

These varied perspectives suggest that while many trainers acknowledge the positive outcomes of the programs, there is still room for improvement in addressing gaps or inconsistencies in their impact, especially for those who reported lower effectiveness levels. Addressing these concerns could help refine program delivery and ensure more widespread success in achieving the desired educational outcomes.

4.2.9 Views of students on whether they would recommend the program to others

Based on the data in Figure 8, a significant majority (85%) of the STEM students, would recommend the training program to others, suggesting a positive evaluation of the program's effectiveness. Only 2% of students expressed dissatisfaction, while 13% remained uncertain about their recommendation. This indicates that the program has had a largely favourable impact on the students' experiences, providing them with the skills and confidence necessary to endorse the program.

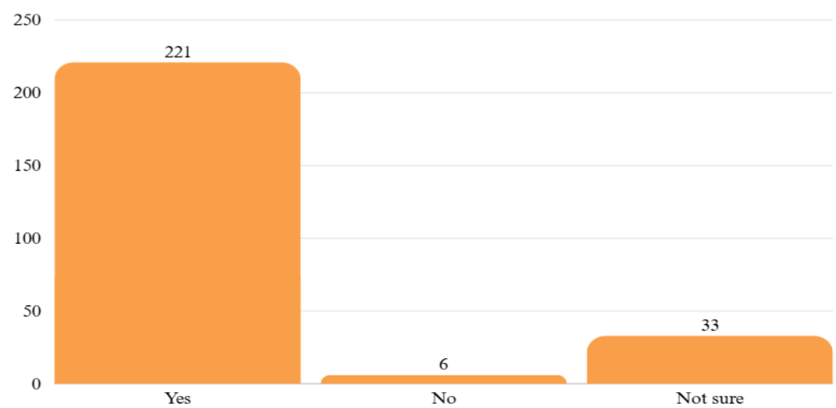

Figure 8: STEM Training Programs Improves Performance and Grades

Source: Primary data from the field (2024)

These results imply that STEM training programs in Ghana are generally perceived as beneficial and successful in meeting the needs of students. However, the 13% who were uncertain about recommending the program highlighted the potential for further improvement, suggesting that addressing their concerns could enhance future respondents' satisfaction and engagement.

4.3 4.4 Research Objective 2: Challenges faced by STEM training programs in Ghana

The finding or result analysed and discussed next will aid in identifying challenges faced by STEM training programs in Ghana

Inadequate Training Materials

Table 4.15 highlights varied perceptions among STEM students in Ghana regarding the adequacy of training and learning resources, a critical component of program effectiveness. While 29.2% (43 Agree and 6 Strongly Agree) of respondents felt that resources were insufficient, a slightly larger proportion of 49.2% (80 Disagree and 45 Strongly Disagree) disagreed with this assertion, indicating relative satisfaction. Interestingly, a significant neutral stance (31.5%) suggests that many respondents were either ambivalent or lacked a clear opinion on the adequacy of resources.

Table 4.15: Students' views on adequacy of training materials

Response	Frequency	Percent
Agree	44	16.9
Strongly Agree	6	2.3
Neutral	82	31.5
Disagree	83	31.9
Strongly Disagree	45	17.3
Total	**260**	**100.0**

Source: Primary data from the field (2024)

These findings suggest that while resource adequacy is not a universal concern, there is still room for improvement in ensuring equitable access to high-quality materials across STEM programs, an essential factor in driving their overall effectiveness in Ghana.

Lack of STEM-dedicated Infrastructure

The data in Table 4.16 reveals mixed views among STEM students in Ghana regarding the adequacy of STEM-dedicated infrastructure as a critical factor in the effectiveness of training programs. While a significant portion of students (33.8%) maintained a neutral stance, a notable 30.4% disagreed and an additional 13.5% strongly disagreed that the lack of dedicated infrastructure posed a challenge. Conversely, only 18.5% agreed and a mere 3.8% strongly agreed with this assertion. These findings suggest that while some students perceive infrastructure as a barrier, the majority either do not view it as a significant issue or remain indifferent.

Table 4.16: Students' views on the lack of STEM-dedicated Infrastructure

Response	**Frequency**	**Percent**
Agree	48	18.5
Disagree	79	30.4
Neutral	88	33.8
Strongly Agree	10	3.8
Strongly Disagree	35	13.5
Total	**260**	**100.0**

Source: Primary data from the field (2024)

This indicates that other factors beyond infrastructure might be more critical in shaping students' experiences and the overall effectiveness of STEM training programs in Ghana, warranting further investigation into areas such as curriculum design, instructional quality, and access to learning resources.

Table 4.17 reveals that majority of trainers (45.4%) either agreed (31.8%) or strongly agreed (13.6%) that a lack of STEM-dedicated infrastructure posed a challenge. This suggests that inadequate facilities may hinder the delivery and impact of STEM education, limiting opportunities for practical and hands-on learning. Meanwhile, 31.8% of respondents were neutral, potentially indicating variability in experiences or perceptions of infrastructure adequacy across different training contexts. Conversely, a smaller proportion disagreed (13.6%) or strongly disagreed (9.1%), suggesting that some trainers may have access to sufficient resources. Overall, the data highlights a critical area for improvement to enhance the effectiveness and accessibility of STEM training programs in Ghana.

Table 4.17: Trainers' views on the lack of STEM-dedicated Infrastructure

Response	**Frequency**	**Percent**
Agree	7	31.8
Disagree	3	13.6
Neutral	7	31.8
Strongly Agree	3	13.6
Strongly Disagree	2	9.1
Total	**22**	**100.0**

Source: Primary data from the field (2024)

Insufficient Time Allocated for STEM Training Programs

The data in Table 4.18 on the perceived time allocation for STEM training programs in Ghana reveals a diversity of opinions among participants, highlighting a potential area for program improvement. Approximately 26.5% of respondents agreed that the time allocated for training was insufficient, with an additional 5.5% strongly agreeing, collectively representing a significant

32.7% of the sample. On the other hand, 21.9% disagreed, and 13.1% strongly disagreed, indicating that 35% of respondents found the time sufficient, while 32.7% remained neutral.

Table 4.18: Students' views on insufficient time allocated to STEM training Programs

Response	**Frequency**	**Percent**
Agree	69	26.5
Disagree	57	21.9
Neutral	85	32.7
Strongly Agree	15	5.8
Strongly Disagree	34	13.1
Total	**260**	**100.0**

Source: Primary data from the field (2024)

This distribution suggests that while some participants are satisfied with the allocated time, a notable proportion perceives it as a challenge, potentially impacting the overall effectiveness of these programs. Addressing this concern by reassessing and optimizing the duration of training sessions could enhance the learning experience and improve outcomes for participants in Ghana's STEM initiatives.

Table 4.19 reveals challenges related to limited time allocated for teaching STEM-related subjects. Analysis of responses from trainers shows that 31.8% of participants agreed, and 22.7% strongly agreed that limited teaching time was a significant challenge, making a total of 54.5% expressing concern. Meanwhile, 31.8% remained neutral, possibly indicating mixed or uncertain perspectives about the adequacy of teaching time. Only 9.1% disagreed, and a minimal 5% strongly disagreed, suggesting that most participants perceive time constraints as an impediment to effective STEM training.

Table 4.19: Trainers' views on insufficient time allocated to STEM training Programs

Response	**Frequency**	**Percent**
Agree	7	31.8
Disagree	2	9.1
Neutral	7	31.8
Strongly Agree	5	22.7
Strongly Disagree	1	4.5
Total	**22**	**100.0**

Source: Primary data from the field (2024)

This finding underscores the need for program designers and policymakers to reconsider scheduling strategies to optimize teaching time and enhance the effectiveness of STEM training programs in Ghana.

Lack of Support from Schools

The data in Table 4.20 on challenges faced during STEM training programs in Ghana highlights that a lack of support from schools is a significant issue, with 18.2% of respondents agreeing and 13.6% strongly agreeing with the statement. However, a considerable portion (27.3%) disagreed, while 9.1% strongly disagreed, indicating variability in experiences. Notably, 31.8% of respondents were neutral, reflecting uncertainty or mixed perceptions about the role of school support.

Table 4.20: Trainers' views on lack of support from schools during trainings

Lack of support from schools	Frequency	Percent
Agree	4	18.2
Disagree	6	27.3
Neutral	7	31.8
Strongly Agree	3	13.6
Strongly Disagree	2	9.1
Total	**22**	**100.0**

Source: Primary data from the field (2024)

These findings suggest that while some trainers perceive insufficient institutional backing as a barrier, others may experience adequate support or attribute challenges to different factors. This disparity underscores the need for a more nuanced understanding of institutional dynamics and tailored interventions to enhance the effectiveness of STEM training programs in Ghana.

Overall Table 4.21 reveals that while 23 respondents (9%) agreed that there were challenges and barriers, a slightly larger proportion of 97 respondents (37%) disagreed, indicating satisfaction with the programme. Interestingly, a significant neutral stance from 140 respondents (54%) suggests that many respondents were either ambivalent or lacked a clear opinion on the challenges and barriers in the STEM programme.

Table 4.21: Students' views on the challenges STEM training programmes encounter

Response	Frequency	Percent
Agree	23	9
Neutral	140	54
Disagree	97	37
Total	**260**	**100**

Source: Primary data from the field (2024)

This pattern aligns with research by Marginson et al. (2013) on STEM education development, suggesting that students may either be adapting well to existing conditions or, as Tikly (2019) notes, may be hesitant to express critical feedback due to cultural or institutional factors.

In comparison, Table 4.22 shows that trainers have demonstrated a markedly different perspective, with 32% (7 respondents) acknowledging challenges such as limited teaching time, inadequate infrastructure, and technology access constraints, while 45% (10 respondents) disagreed about barriers, and 23% (5 respondents) remained neutral. This higher recognition of challenges by trainers reflects findings by UNESCO (2019) on STEM education in developing countries, which identifies resource and infrastructure limitations as persistent obstacles to effective program delivery.

Table 4.22: Trainers' views on the challenges STEM training programmes encounter

Response	Frequency	Percent
Agree	7	32
Neutral	5	23
Disagree	10	45
Total	**22**	**100**

Source: Primary data from the field (2024)

4.3.2 Areas of Improvement for STEM training programs

The evaluation of STEM training programs in Ghana reveals key areas requiring improvement, as identified by STEM trainers. The data from Table 4.23 indicates that the most critical challenge is inadequate technology, cited by 40% of respondents, highlighting the need for modern tools and resources to enhance training effectiveness. Practical aspects, including the availability of kits, account for 25%, reflecting the necessity for hands-on learning materials to complement theoretical instruction. Funding challenges and course implementation issues were noted by 15% and 10% of respondents, respectively, underscoring the financial and structural barriers hindering program efficiency. Additionally, the duration of courses was flagged by 10% as a concern, suggesting a need to reassess program timelines for optimal skill acquisition.

Table 4.23: Aspects of STEM training programs in Ghana need the most improvement

Aspects That Need Improvements	Frequency	Percent
Duration of courses	2	10.0
Funding for the program	3	15.0
Implementation	2	10.0
Practical aspects requiring kits	6	25.0
Technology	9	40.0
Total	**22**	**100.0**

Source: Primary data from the field (2024)

These findings emphasize the importance of addressing technological and practical gaps, alongside resource allocation and program structure, to improve the overall impact of STEM training in Ghana.

4.4 Research Objective 3: Sustainability measures and level of collaboration among stakeholders

The finding analysed and discussed next will aid in identifying sustainability and collaborative mechanisms employed by trainers in enhancing effectiveness of STEM training programs

4.4.1 Contribution of Trainers to Sustainability of STEM Training Programs

The data in Table 4.24 highlights the contribution of STEM trainers to the sustainability of training programs in Ghana. Most respondents (55%) indicated that they always engage in these activities, while 9% reported doing so sometimes. However, a smaller proportion (36%) never engage in these practices, suggesting that while a significant number of trainers are actively contributing to the sustainability of the programs, there is room for broader involvement to ensure long-term impact and consistency.

Table 4.24: Contribution to sustainability

Response	**Frequency**	**Percent**
Always	12	55
Sometimes	2	9
Never	8	36
Total	**22**	**100**

Source: Primary data from the field (2024)

Scholarly literature by Mtebe and Raphael (2018) supports the observation that trainer contributions are critical to program longevity, with the current study showing that 55% of trainers consistently develop reusable materials, share content, and provide follow-up support. This aligns with capacity-building theories that emphasize the importance of continuous professional development and knowledge transfer beyond initial training interventions.

4.4.2 Trainer's view on how to financially sustain STEM training programs

The data from STEM trainers in Table 4.25 highlights key perspectives on sustaining STEM training programmes in Ghana, with a significant emphasis on partnerships and external funding. Of the 22 respondents, 46% identified partnerships with educational institutions as the most viable option for financial sustainability. This perspective aligns with scholarly research by Kruss et al. (2015), which emphasizes the transformative potential of inter-institutional collaborations in resource mobilization. Additionally, 23% emphasized the importance of consistent corporate funding and government grants or support. Anderson and Adserias (2019) support this multi-stakeholder approach, highlighting how hybrid funding models can create more resilient educational programs.

Table 4.25: What is needed to financially sustain these STEM programs

Financial Sustainability	Frequency	Percent
Consistent corporate funding	5	23.0
Government grants or support	5	23.0
Not sure about financial aspects	2	9.0
Partnerships with educational institutions	10	46.0
Total	20	100.0

Source: Primary data from the field (2024)

The balanced perspective suggests trainers recognize the complementary roles of private sector investment and public policy in supporting STEM education initiatives, particularly in developing contexts like Ghana. However, 9% of respondents were unsure about financial aspects, indicating a potential gap in knowledge or experience regarding funding mechanisms.

4.4.3 Collaboration with External stakeholders

The data in Table 4.26 reveals that a significant majority (91%) of STEM trainers in Ghana collaborate with other stakeholders, including schools, corporations, and government entities, before implementing STEM training programmes. This high level of stakeholder engagement suggests a strategic and inclusive approach to programme design and execution, which is likely to enhance the relevance, resource availability, and sustainability of these initiatives. Conversely, the

9% who do not engage in such collaborations may face limitations in programme impact due to reduced access to partnerships and support.

Table 4.26: Collaboration with other stakeholders

Response	Frequency	Percent
No	2	9
Yes	20	91
Total	**22**	**100**

Source: Primary data from the field (2024)

Overall, the findings underscore the critical role of multi-stakeholder partnerships in fostering effective STEM training programmes that address local needs and align with broader educational and industrial objectives, ultimately enhancing the sustainability of these programmes.

4.4.5 Evaluation of STEM Training Programs

Whether students were contacted evaluate the programs

Data gathered from students as shown in Table 4.27 reveals that 71% of STEM students reported being contacted for program evaluation, while 29% indicated otherwise. This suggests a strong emphasis on gathering feedback from respondents, which is crucial for assessing the effectiveness of STEM training programs in Ghana. The high engagement rate demonstrates a proactive approach by program implementers to involve beneficiaries in the evaluation process, potentially allowing for tailored improvements based on participant insights. However, the 29% who were not reached highlight the need for more inclusive feedback mechanisms to ensure comprehensive evaluations that reflect diverse perspectives within the STEM student population.

Table 4.27: Evaluation of Program by Students

Response	Frequency	Percent
No	76	29
Yes	184	71
Total	**260**	**100**

Source: Primary data from the field (2024)

This data underscores the importance of robust evaluation frameworks to enhance the quality and impact of STEM training initiatives in Ghana, ensuring that future programs are better aligned with students' needs and expectations.

Students' Mode of Evaluation

Further analysis from data gathered from students as shown in Table 4.28 revealed that a significant proportion, 40%, indicated that surveys were employed to evaluate the programs, suggesting that surveys are a prevalent method for gauging participant feedback and program impact. Interviews were utilized by 23% of respondents, and focus group discussions were used by 15%, indicating a moderate reliance on more interactive and qualitative approaches to data collection. Additionally, 22% of respondents reported that no evaluation was conducted, and a small fraction (1%) noted that evaluations were not done. This data highlights that while surveys are the primary evaluation tool, there is a need for improvement in comprehensive evaluation methods for STEM training programs in Ghana.

Table 4.28: How was the evaluation done?

Evaluation Mode	**Frequency**	**Percent**
Focus group discussion	38	15
Interview	60	23
None	55	22
Not done	3	1
Survey	104	40
Total	**255**	**100.0**

Source: Primary data from the field (2024)

The findings suggest that incorporating a broader range of evaluation methods, such as in-depth interviews or regular feedback loops, could enhance the ability to assess the programs' effectiveness and identify areas for improvement. Ensuring a more robust and diversified approach to program evaluation will provide a clearer picture of the programs' impact and help drive continuous improvement in STEM education in Ghana.

Trainers' Mode of Evaluation

The evaluation of the effectiveness of STEM training programs in Ghana as indicated in Table 4.29 reveals diverse approaches employed by trainers to assess their impact on students. According to the data, pre- and post-tests are the most frequently used method, accounting for 55% of responses, highlighting their importance in measuring knowledge acquisition and skill development over time. Project evaluations are also widely utilized (32%), emphasizing the role of hands-on, practical assessments in understanding students' application of STEM concepts.

Surveys, though less common (9%), provide valuable insights into respondents' perceptions and feedback, which are crucial for identifying areas for programme improvement.

Table 4.29: How do you as a trainer assess the impact of your training on students?

Mode of Assessment	Frequency	Percent
Pre and post-tests	12	55
Project evaluations	7	32
Surveys	2	9
Mostly Do Not Assess	1	4
Total	**22**	**100**

Source: Primary data from the field (2024)

4.4.6 Mechanism for Long Term- Follow up

The findings from the survey of STEM trainers reveal mixed perspectives on the presence of long-term follow-up mechanisms with students after training which is a critical component in evaluating the sustained impact of STEM programs in Ghana. From Table 4.30, out of the 22 trainers surveyed, 32% confirmed the existence of follow-up mechanisms, indicating that some initiatives are in place to monitor and support students post-training. However, 41% reported that no such mechanisms exist, highlighting a potential gap in ensuring the long-term effectiveness of these programs. Additionally, 27% of respondents were uncertain, suggesting a lack of clarity or communication about follow-up processes within the system.

Table 4.30: Are there mechanisms in place for long-term follow-up

Responses	**Frequency**	**Percent**
No	9	41.0
Not Sure	6	27.0
Yes	7	32.0
Total	**22**	**100.0**

Source: Primary data from the field (2024)

These findings underscore the need for more consistent and transparent follow-up strategies to track student progress, measure the impact of STEM training, and identify areas for improvement to enhance the program's overall effectiveness. It resonates with scholarly research by Gachanja (2016) on capacity-building programs in developing educational contexts, which emphasizes the critical importance of sustained engagement beyond initial training.

4.4.7 Recommendations to enhance effectiveness of STEM Training Programmes

The findings as shown in Table 4.231 suggest several potential areas for strengthening STEM training programmes in Ghana. The lack of recommendations from 40% of respondents could reflect either disengagement or a lack of clarity regarding effective strategies for program improvement. However, for those who provided input, the emphasis on partnerships with STEM organizations (25%) indicates that collaboration could enhance the quality and scope of these programs as supported by Kruss et al. (2015), highlighting the transformative potential of inter-organizational collaborations in educational development.

Table 4.31: Specific recommendations for enhancing the impact of these programs

Recommendations	Frequency	Percent
More investment in STEM curriculum development	2	10.0
No	9	40.0
Partnership with STEM organizations	6	25.0
Provision of STEM infrastructure	3	15.0
STEM education awareness	2	10.0
Total	**22**	**100.0**

Source: Primary data from the field (2024)

The call for better STEM infrastructure (15%) highlights the need for both physical and technological resources to create conducive learning environments. Additionally, suggestions for more investment in STEM curriculum development and increased public awareness (10% each) point to the necessity of updating educational content and promoting STEM fields to a wider audience. These insights suggest that addressing these key areas—partnerships, infrastructure, curriculum development, and public awareness—could significantly improve the effectiveness of STEM training programs in Ghana.

4.5 Discussion of Findings

The findings of this study align with and extend existing scholarly literature while providing novel insights into the impact, challenges, and sustainability of STEM training programs in Ghana. These findings also reveal critical connections to theoretical frameworks such as sustainability theory and systems theory, which offer a lens through which to interpret the data.

The study shows a predominantly youthful demographic among both students and trainers in STEM programs, with 65% of students aged 22 and above and 55% of trainers within the 18–25 age range. These trends highlight an increasing appeal of STEM fields among younger individuals. This aligns with studies by Marginson et al. (2013), which emphasize the role of early exposure to STEM in fostering long-term engagement.

The gender distribution revealed moderate disparities, with males comprising 54% of students and a balanced gender ratio among trainers. These findings reflect progress toward gender equity but highlight the need for further initiatives to close existing gaps, as emphasized by UNESCO (2023). The study revealed a predominantly positive reception of STEM training programs, with 66% of students agreeing that the programs are relevant and impactful. These findings are corroborated by Danquah & Mensah (2022), who emphasize that well-designed STEM programs enhance knowledge, skills, and attitudes toward STEM fields.

The data also highlighted the significant improvement in practical skills (65% agreed or strongly agreed) and critical thinking (84% reported high effects). These outcomes are consistent with studies by Abrami et al. (2015) and Freeman et al. (2014), which found that active learning and hands-on approaches significantly improve critical thinking and problem-solving skills in STEM contexts. Systems theory supports this finding by suggesting that interconnected elements, such as training content and delivery methods, enhance overall program outcomes.

Resource constraints, inadequate infrastructure, and time limitations emerged as significant challenges. These findings align with Arkorful et al. (2021) and Anamuah-Mensah & Mereku (2020), who identify similar barriers in STEM education in Africa. Interestingly, the "awareness gap" between trainers (32% acknowledged challenges) and students (9% acknowledged challenges) reflects differences in perceptions, as noted by Ottevanger et al. (2018).

Sustainability theory links these challenges to the need for systemic solutions that integrate financial, technological, and human resource investments to ensure long-term program viability. The study highlighted significant collaboration among stakeholders, with 91% of trainers engaging external entities to support program delivery. This is consistent with Kruss et al. (2015), who emphasize the importance of multi-stakeholder partnerships in sustaining educational initiatives. Partnerships with corporations and educational institutions, identified as critical by 46% of trainers, reflect an alignment with sustainability theory, which emphasizes long-term strategies through resource pooling and cooperative efforts.

Furthermore, the study revealed that 63% of students received training materials, and 55% of trainers consistently engaged in sustainability activities. However, gaps in long-term follow-up mechanisms (only 32% confirmed their existence) indicate areas for improvement, as underscored by Gachanja (2016). Systems theory justifies these findings by framing STEM training programs as dynamic systems where feedback loops and interconnected components, such as follow-ups and material provision, influence overall effectiveness. Respondents recommended partnerships with STEM organizations (25%), improved infrastructure (15%), and curriculum development (10%) as critical areas for enhancement. These align with recommendations from Anderson & Adserias (2019) for leveraging hybrid funding models and Kruss et al. (2015) on enhancing institutional collaborations.

The emphasis on program manuals and subject-specific talks supports findings by Batchelor et al. (2014), who highlight the importance of structured, practical resources for improving STEM education outcomes

4.6 Chapter Summary

This chapter provided a comprehensive overview of the demographic characteristics, perceptions, and experiences of respondents in STEM training programs in Ghana. It highlighted the youthful demographic of both students and trainers, moderate gender disparities, and the generally positive reception of these programs in enhancing knowledge, practical skills, and critical thinking. The chapter identified significant challenges such as resource constraints, inadequate infrastructure, and time limitations while underscoring the importance of stakeholder collaboration for program sustainability. Recommendations for improvement included fostering partnerships, enhancing infrastructure, and refining curriculum development. The findings aligned with theoretical frameworks like sustainability and systems theory, emphasizing interconnectedness and long-term strategies to address barriers and maximize program impact. These insights provided a robust foundation for addressing gaps and advancing STEM education in Ghana

CHAPTER FIVE

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

5.0 Introduction

The landscape of STEM education in Ghana represents a critical juncture of educational innovation, technological advancement, and socio-economic transformation. This research provides an in-depth exploration of STEM training programs, aiming to unravel the complex dynamics of their implementation, effectiveness, and potential for meaningful educational impact. The current chapter synthesizes the extensive findings, offering a comprehensive understanding of STEM training in Ghana and presenting strategic recommendations for future development.

5.1 Summary of Findings

This research aimed to investigate the effectiveness, challenges, and sustainability of STEM training programs in Ghana. A quantitative research design was employed, utilizing a cross-sectional survey approach to capture data at a single point in time. The study population comprised university students who participated in STEM programs, project coordinators at senior high schools, and corporate trainers responsible for program delivery. **A** sample size of 282 respondents was drawn, made up of 260 university students and 22 corporate trainers, selected using simple random sampling and convenience sampling techniques, respectively. Data were collected using structured questionnaires with close-ended questions and Likert-scale items, ensuring efficient capture of quantitative information. The data were analysed using IBM SPSS software**,** employing descriptive statistical techniques to summarize participant responses and identify relationships between variables.

5.1.1 Program Effectiveness and Impact Evaluation

The study revealed a multifaceted landscape of program effectiveness that defies simplistic categorization. The perceptions of program success among trainers demonstrated remarkable complexity and nuance:

Trainer Effectiveness Perceptions: The research uncovered a diverse range of perspectives regarding the effectiveness of STEM training programs. A significant proportion of trainers (46%) reported that the programs were effective to a great extent, indicating substantial confidence in the educational approach. However, this optimistic view was not universally shared. Twenty-seven percent of trainers viewed the effectiveness as moderate, suggesting there are notable areas requiring improvement. An additional 18% perceived the effectiveness as limited, highlighting potential systemic challenges in program delivery.

The most intriguing aspect of the effectiveness analysis was the polarized views at the extremes. A small but significant minority of trainers (5%) found the programs completely successful, reflecting exceptional implementation in some contexts. Conversely, another 5% perceived no effectiveness at all, underscoring the variability in program implementation and outcomes.

Student Engagement and Perception: In contrast to the varied trainer perspectives, students presented a notably more positive narrative. An impressive 85% of students expressed willingness to recommend the training program to their peers, indicating a strong positive experience. This high recommendation rate suggests that despite institutional challenges, the programs successfully engage and motivate students at an individual level.

The discrepancy between trainer and student perspectives illuminates the complex nature of STEM training programs in Ghana. It suggests that institutional challenges and systemic limitations may not entirely overshadow the individual learning experiences and personal growth opportunities provided by these programs.

5.1.2 Systemic Challenges and Institutional Barriers

The research meticulously identified and analysed critical challenges confronting STEM training programs across multiple dimensions:

Technological Infrastructure Limitations: A substantial 40% of trainers identified technological inadequacies as the primary challenge facing STEM training programs. These limitations manifest in several critical areas: significant gaps in digital learning resources, restricted technological access, and a shortage of modern educational tools. The technological constraints represent more than mere infrastructure problems; they symbolize a broader challenge of bridging the digital divide in educational contexts.

Practical Learning Resource Constraints: Twenty-five percent of trainers highlighted the insufficient practical learning materials as a significant impediment to effective STEM education. The key issues include a notable disconnect between theoretical instruction and practical application, limited hands-on learning opportunities, and inadequate experimental resources.

These constraints potentially compromise the students' ability to develop critical practical skills essential for real-world STEM applications.

Structural and Financial Constraints: The research unveiled complex funding challenges that impact program quality and implementation. Inconsistent resource allocation and structural barriers create additional layers of complexity in delivering effective STEM training. These financial constraints extend beyond mere monetary limitations, reflecting deeper systemic issues in educational resource management.

Awareness and Perception Gap: A particularly significant finding was the substantial "awareness gap" between student and trainer perceptions of systemic challenges. While 32% of trainers could articulate comprehensive institutional barriers, only 9% of students demonstrated similar systemic awareness. This disparity suggests deeper institutional complexities that may not be immediately apparent to program participants.

5.1.3 Sustainability and Collaborative Mechanisms

The study unveiled promising collaborative approaches that offer potential pathways for program enhancement:

Sustainability Initiatives: Fifty-five percent of trainers consistently engaged in activities focused on program sustainability, demonstrating a proactive approach to long-term educational development. These efforts indicate a commitment to continuous improvement and systematic enhancement of STEM training programs.

Stakeholder Collaboration: A remarkable 91% of trainers collaborated with external stakeholders, revealing a robust ecosystem of inter-institutional cooperation. This high collaboration rate suggests a dynamic and responsive educational landscape capable of adapting to evolving technological and educational demands.

Financial Sustainability Strategies: Forty-six percent of trainers identified partnerships with educational institutions as crucial for financial sustainability. This perspective highlights the importance of developing comprehensive, multi-stakeholder funding models that can support ongoing STEM education initiatives.

Evaluation Methodologies: The research identified diverse program evaluation methods, with pre- and post-tests being the most prevalent (55%). This approach indicates a structured mechanism for assessing program effectiveness and student learning outcomes.

5.2 Conclusions

This study explored the effectiveness, challenges, and sustainability of STEM training programs in Ghana through a quantitative research design. Based on the specific objectives and key findings, the following conclusions were drawn:

STEM training programs in Ghana have demonstrated significant potential in positively influencing student engagement and personal growth. A high percentage of students (85%) were willing to recommend the programs, indicating their overall satisfaction and perceived benefits. However, the effectiveness as perceived by trainers varied, with 46% rating the programs highly, while others identified areas for improvement. The disparity between trainer and student perceptions underscores a nuanced landscape where institutional challenges may coexist with individual student successes.

Critical challenges persist within STEM training programs, particularly in technological infrastructure, practical learning resources, and financial sustainability. Forty percent of trainers cited technological inadequacies as a major limitation, while 25% emphasized the lack of practical learning materials, reflecting a significant gap between theoretical knowledge and hands-on application. Financial constraints and inconsistent resource allocation further compound these challenges. Additionally, the awareness gap between trainers (32%) and students (9%) regarding systemic challenges highlights the need for increased transparency and dialogue about program limitations.

Efforts to ensure the sustainability of STEM programs showed promise, with 55% of trainers actively engaging in sustainability-focused initiatives. Stakeholder collaboration emerged as a key strength, with 91% of trainers working with external partners, indicating a robust support system. Financial sustainability strategies, particularly partnerships with educational institutions, were identified as critical, reflecting the necessity of multi-stakeholder approaches to ensure long-term program viability. The use of structured evaluation methods, such as pre- and post-tests (55%), demonstrated an emphasis on assessing program impact and fostering continuous improvement.

Overall, while STEM training programs in Ghana have made notable strides in engaging students and promoting STEM education, systemic challenges such as resource limitations and structural barriers require targeted interventions. The strong collaborative mechanisms and sustainability initiatives provide a foundation for addressing these issues and enhancing the overall effectiveness and resilience of STEM education in Ghana.

5.3 Recommendations

The following recommendations are suggested;

1. Enhance Technological Infrastructure

To address the significant technological limitations identified, stakeholders should prioritize the provision of modern digital learning tools and resources in STEM training programs. Government and private sector collaboration can help bridge the digital divide by supplying schools and training centres with up-to-date hardware, software, and internet connectivity. This initiative should include regular maintenance and upgrades to ensure technological relevance and sustainability.

2. Invest in Practical Learning Resources

The lack of hands-on learning opportunities requires immediate attention. STEM programs should integrate practical components, such as laboratories, kits, and real-world project-based learning activities, to complement theoretical instruction. Partnerships with industry players can provide access to modern equipment and facilitate experiential learning opportunities, thereby enhancing the development of practical skills essential for STEM careers.

3. Address Structural and Financial Barriers

Sustainable funding mechanisms must be established to support STEM training programs. Policymakers should develop frameworks that encourage public-private partnerships, enabling consistent resource allocation. Additionally, education authorities must improve resource management systems to ensure equitable distribution of funds and materials across institutions, particularly in underserved regions. Introducing dedicated STEM grants for schools and trainers could also alleviate financial pressures.

4. Narrow the Awareness and Perception Gap

The disparity between student and trainer perceptions of systemic challenges highlights the need for increased transparency and communication. Regular feedback mechanisms, such as focus group discussions and surveys, should be implemented to bridge this gap. Trainers and program implementers should provide students with insights into the broader challenges of program delivery, fostering a shared understanding of institutional barriers and collaborative solutions.

5. Strengthen Sustainability and Collaboration Mechanisms

To build on the promising sustainability initiatives observed, trainers and institutions should formalize their efforts through documented strategies and continuous engagement with stakeholders. Expanding collaborations with educational institutions, corporations, and non-governmental organizations can provide a steady influx of resources and expertise. Establishing STEM advisory boards comprising industry leaders, educators, and policymakers can ensure alignment between program content and labour market demands.

6. Develop Comprehensive Evaluation Frameworks

The reliance on pre- and post-tests for evaluation should be supplemented with diverse methodologies, such as longitudinal studies, performance-based assessments, and regular program audits. This will provide a more holistic understanding of program effectiveness and long-term impact. Trainers should receive training in evaluation techniques to ensure accurate data collection and analysis for continuous program improvement.

7. Enhance Financial Sustainability Strategies

Educational institutions must prioritize developing robust multi-stakeholder funding models. Encouraging partnerships with private organizations, fostering corporate sponsorships, and advocating for government grants are essential strategies to secure long-term financial stability. Initiatives such as tax incentives for corporations supporting STEM education could further enhance funding avenues

5.4 Limitations

The study acknowledges several critical limitations that provide context for interpreting the research findings:

Sample Size and Representativeness: The research was constrained by a relatively limited sample size, comprising 22 trainers and a restricted number of student respondents. This limitation potentially impacts the broader generalizability of the findings. While the insights provide valuable perspectives, they may not comprehensively represent the entire spectrum of STEM training experiences across Ghana.

Geographical Concentration: The research was primarily focused on specific regions within Ghana, which introduces potential geographical bias. The findings may not fully capture the nuanced variations that might exist in different geographical and socio-economic contexts across the country. This concentration limits the potential for comprehensive national-level insights.

Respondent Bias Considerations: The study recognizes the potential for respondent bias in self-reported data. Trainers and students may have inherent limitations in their ability to provide completely objective assessments of the STEM training programs. Factors such as institutional loyalty, personal experiences, and individual perceptions could influence the reported outcomes.

Longitudinal Data Constraints: The research was limited in its ability to capture long-term outcomes and impacts of STEM training programs. The lack of extensive longitudinal data restricts the ability to trace the career trajectories and long-term professional development of program participants. This limitation prevents a comprehensive assessment of the programs' ultimate effectiveness and transformative potential.

5.5 Suggestions for Future Research

The study identifies several critical areas for future investigation:

1. Future research should focus on longitudinal studies to track the long-term impact of STEM training programs on students' academic performance, career choices, and professional development. This would provide deeper insights into the sustainability and effectiveness of these programs over time.
2. Investigate the specific barriers and enablers influencing gender participation in STEM training programs. Research could explore how cultural, social, and institutional factors contribute to disparities and identify targeted interventions to promote gender equity in STEM fields.
3. Examine the role of multi-stakeholder collaborations (government, private sector, NGOs) in shaping the success and sustainability of STEM education initiatives. This research could assess how partnerships influence resource allocation, program design, and scalability.

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APPENDIX I

Questionnaires for Students

Dear respondent, I am a Master of Arts student of the University of Media Arts and Communications conducting a study on "Evaluating the Effectiveness of STEM Training Programs in Ghana", using University of Ghana, GTUC and KNUST as a case study. Your participation in this questionnaire is greatly appreciated.

Please note that all responses will be kept confidential and used solely for research purposes. We assure you that your identity will remain anonymous, and your answers will never be shared individually. Kindly read the questions carefully before answering. There are no right or wrong answers, your honest responses will greatly contribute to this research. Thank you.

Section A: Demographic Information

1. Age

    [] 18-21

    [] 22 and above

2. Gender

    [] Male

    [] Female

3. Name of school:

    ____

4. The following are STEM training programs, tick as many as you have participated in:

STEM PROGRAM	TICK
Girls Can Code	
Tullow Educate to Innovate	
ABL STEM Education Support	
GNPC STEM Education Support Program	
Girls In ICT	
Huawei Women in Tech	
Newmont Ahafo Development Foundation STEM Program	
MTN Bright Scholarship and ICT Training	
The Mastercard Foundation Scholars Program	
Kosmos Innovation Center (KIC) AgriTech Challenge	

[] Other______________________

5. On average, how long was the STEM training program you participated in?

[] Less than a week

[] 1-4 weeks

[] 1-3 months

[] More than 3 months

Section B: View on the STEM Training Programmes

The following statements relate to aspects of STEM training programmes. Please, indicate the extent to which you agree or otherwise to these statements using a scale of: 5=Strongly Agree, 4=Agree, 3=Neutral, 2=Disagree, 1=Strongly Disagree.

ITEM	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
The content of the training was relevant to my needs/interests					
The delivery methods helped to enhance my understanding of the programmes.					
The course objectives were clear and specific.					
The environment where the programmes took place was conducive to me.					
The training improved my knowledge about STEM subjects					
The training enhanced my practical skills in STEM fields					
Through this training I am able to use basic ICT tools and software					

After the training I have been confident in solving STEM problems					
The training encouraged me to come up with my own ideas and be creative					
The training positively influenced my attitude towards STEM fields					
The trainer had expertise hence I easily understood what he taught					
Overall the programme met my expectation					

Section C: Perceived Effect of the Programmes

6. The following statements relate to outcomes of STEM programmes. To what extent do you perceive the effect of the programmes you participated in on you based on these statements using a scale of: 5=High Effect, 4=Moderate Effect, 3=Low Effect, 2=No Effect, 1=Neutral.

Item	High Effect	Moderate Effect	Low Effect	No Effect	Neutral
Problem-solving					
Critical thinking					
Teamwork					
Communication					

Technical skills (e.g., coding, lab techniques)					
Leadership ability					
Collaborative skills					
Innovative and creative skills					
Digital literacy					

[] Other (please specify) ________________________

7. Has the STEM training program improved your performance and grades in STEM subjects?

    [] Not at all

    [] Slightly

    [] Moderately

    [] Significantly

    [] Very significantly

8. Which skills do you feel have improved as a result of the program? (Select all that apply)

    [] Problem-solving

    [] Critical thinking

    [] Teamwork

    [] Communication

    [] Technical skills (e.g., coding, lab techniques)

    [] Basic ICT skills

    [] Other (please specify): ________________________

9. Have you applied any knowledge or skills from the program in your regular studies?

    [] Yes

    [] No

    If yes, please provide an example: ______________________

10. Has the program increased/ changed your interest in pursuing a STEM career?

    [] Yes

    [] No

    [] Not sure

11. What STEM career(s) were you most interested in after participating in this program?

    ____

12. Did it inform your decision in selecting the course you are offering at the university?

    [] Yes

    [] No

    [] Partially

    Please explain: ______________________

<u>Section D: Challenges and Barriers</u>

13. Please rate the following challenges you may have encountered during the STEM training program. Use the scale below to indicate your level of agreement with each statement 5=Strongly Agree, 4=Agree, 3=Neutral, 2=Disagree, 1=Strongly Disagree.

Challenges	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I had difficulty understanding the content					
The training/ learning resources were inadequate					
Limited certified STEM-dedicated teachers					
Lack of STEM-dedicated infrastructure					
There was insufficient time allocated for the training					
The training did not suit my needs at the moment					
I received low support from my school or family					

[] Other (please specify): ________________________

Section E: Sustainability

14. Were training materials provided after the training?

[] Yes

[] No

15. If yes, were the training materials relevant to you?

[] Yes

[] No

[] Not sure

16. Did anyone reach out to you to evaluate the program?

[] Yes

[] No

17. If yes how was the evaluation done?

[] Interview

[] Survey

[] Focus group discussion

[] Other (please specify) ______________________

18. Would you recommend this STEM training program to other students?

[] Yes

[] No

[] Not sure

Thank you for your participation in this survey. Your input is valuable for improving STEM training programs in Ghana.

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Questionnaires for Corporate Trainers

Dear respondent, I am a Master of Arts student of the University of Media Arts and Communications conducting a study on “Evaluating the Effectiveness of STEM Training Programs in Ghana”, using University of Ghana, GTUC and KNUST as a case study. Your participation in this questionnaire is greatly appreciated.

Please note that all responses will be kept confidential and used solely for research purposes. We assure you that your identity will remain anonymous, and your answers will never be shared individually. Kindly read the questions carefully before answering. There are no right or wrong answers, your honest responses will greatly contribute to this research. Thank you.

Section A: Demographic Information

1. Age

[] 18-25

[] 26-35

[] 36- 45

[] 45 and above

2. Gender

[] Male

[] Female

3. Highest level of education:

[] Bachelor's Degree

[] Master's Degree

[] PhD

[] Other (please specify): ________________________

4. Field of expertise: _______________________

5. Years of experience as a STEM trainer:

[] 0-3

[] 3-6

[] 6-10

[] 11+

Section B: Program Structure and Implementation

6. What type of STEM training programs do you conduct? (Select all that apply)

[] Short workshops (1-3 days)

[] Extended courses (1-4 weeks)

[] Long-term programs (1-3 months)

[] Other (please specify): _______________________

7. On average, how many students participate in your training sessions?

[] Less than 10

[] 10-20

[] 21-30

[] More than 30

8. Do you have access to adequate resources and equipment for your training sessions?

   [] Yes, always

   [] Most of the time

   [] Sometimes

   [] Rarely

   [] Never

9. What teaching methods or strategies do you mostly use during the STEM education? (Select all that apply)

   [] Hands-on experiments

   [] Project-based learning

   [] Inquiry-based learning

   [] Lectures

   [] Group discussions

   [] Other (please specify): ______________________

Section C: Perceived Effect of the Programmes

10. The following statements relate to outcomes of STEM programmes. To what extent do you perceive the effect of the programmes on participants Using a scale of: 5=High Effect, 4=Moderate Effect, 3=Low Effect, 2=No Effect, 1=Neutral

Item	High Effect	Moderate Effect	Low Effect	No Effect	Neutral
Increased subject knowledge					
Critical Thinking Skills					
Problem-solving skills					
Technical skills					
Collaborative Skills					
Interest in STEM fields					
Enhanced practical skills					
Innovative and Creative skills					
Communication skills					
Teamwork					

[] Other (please specify) ________________________

11. How do you assess the impact of your trainings on students?

    [] Pre and post-tests

    [] Project evaluations

    [] Surveys

    [] Observation of student engagement

    [] Long term follows ups

    [] Other (please specify) ________________________

12. To what extent do you believe the programs achieve their intended objectives?

[] Not at all

[] To a small extent

[] To a moderate extent

[] To a great extent

[] Completely

Section D: Challenges and Support

13. Please indicate your level of agreement with the following statements about challenges you encountered during the STEM training program. Use the scale below to indicate your level of agreement with each statement 5=Strongly Agree, 4=Agree, 3=Neutral, 2=Disagree, 1=Strongly Disagree.

Item	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Inadequate STEM teaching material					
Lack of appropriate STEM-dedicated infrastructure					
Limited number of certified STEM Teachers					
Inadequate professional development opportunity					

Limited time for teaching STEM-related subjects					
Class size was too large					
Varied students' skills level					
Lack of support from schools					
Limited access to technology					
Absence of standardized STEM curriculum					

[] Other (please specify): ______________________

14. How often do you receive professional development or training to enhance your skills as a STEM trainer?

[] Never

[] Rarely (less than once a year)

[] Annually

[] Several times a year

[] Quarterly

[] More frequently

Section E: Collaboration and Sustainability

15. Do you collaborate with other stakeholders (e.g., schools, corporations, government) before implementing STEM training programs?

    [] Yes

    [] No

    If yes, please describe the nature of this collaboration: ______________________

16. Are there mechanisms in place for long-term follow-up with students after the training?

    [] Yes

    [] No

    [] Not sure

    If yes, please describe: ______________________

17. How do you contribute to the sustainability of STEM training programs? Use the scale below to rate the statements 5=Always, 4=Often, 3=Sometimes, 2=Rarely, 1=Never.

Item	Always	Often	Sometimes	Rarely	Never
Develop reusable training materials					
Share training content with schools to enhance project continuity					
Train other potential trainers to expand program reach					

Provide follow-up support to students after the training					
Offer suggestions for program improvements to project coordinators					
Help schools integrate STEM activities into their curriculum					
Adapt content to local community needs and interests					
Collect and analyse feedback from students to improve future sessions					
Assist in identifying potential funding sources					
Participate in long-term evaluation of program impacts					

18. From your perspective, what do you think is needed to financially sustain these STEM programs?

[] Consistent corporate funding

[] Government grants or support

[] Partnerships with educational institutions

[] Student/parent contributions

[] Not sure about financial aspects

[] Other: ______________________

19. What aspects of STEM training programs in Ghana need the most improvement?

    ____

20. Do you have any specific recommendations for enhancing the impact of these programs?

    ____

Thank you for your participation in this survey. Your input is valuable for improving STEM training programs in Ghana.

https://docs.google.com/forms/d/18lxbW8SLM0AWie5jrh9hFZpolfXs9dxgmmjqj3aO0k/edit#responses