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Investigating Factors to be Considered for Successful STEM Integration Education in Ghana

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ABSTRACT: *The purpose of the study was to investigate into the main factors to consider for successful STEM integration education as Ghana decides to incorporate STEM education into its educational curriculum. The study used concurrent mixed method as the study design and purposive and snowball sampling to sample thirteen (13) stakeholders for the study. The instruments used for the data collection were questionnaire items for the quantitative part and a semi-structured interview for the qualitative part. All thirteen respondents answered the questionnaire whereas 12 respondents availed themselves for the interview. The data gathered were analysed separately yet concurrently. The findings reveal that for a successful STEM education in Ghana there is a need to look at capacity building of teachers which is paramount, interest of students, etc. The study recommends that the Ghana Education Service must ensure that well qualified STEM teachers are recruited into our schools. Heads of institutions must ensure there is continuous professional development of their teachers.*

KEYWORDS: STEM integration, STEM education, educational curriculum. main factors, successful STEM education

INTRODUCTION

Science, Technology, Engineering, and Mathematics (STEM) education is at the forefront of integrated approaches to our modern-day education system. It involves educational activities across all grade levels from pre-school to post-doctorate in both formal and informal settings (Gonzalez and Kuenzi, 2012). STEM is an approach to teaching and learning that integrates the content and skills of the STEM disciplines and other disciplines. STEM therefore, embodies on interdisciplinary and applied approaches to teaching that focuses on the development of transversal competences, and according to Timms, Moyle, Weldon, and Mitchell (2018, p.2), "STEM involves students working scientifically. mathematically, digitally or technologically, and working like an engineer'. Indeed, STEM integration education is the surest way to go for every nation in the 21st century. STEM education has the potential of helping students develop the 21st century competencies including critical thinking, problem solving, etc.

Excellence in STEM education can have impact on jobs, productivity, and foster competitiveness in multiple sectors and fields including health, technological innovation, manufacturing, the distribution of information, political processes and cultural change (Peters, 2006; Asunda, 2014). Innovation in STEM fields drives not only economic growth but also the quality of life. To buttress the impacts of STEM education on social life, Petroski (2010) posited that STEM education plays an important role in the development of society and can protect real life. The other argument for STEM literacy has to do with urgent economic needs. A common theme that runs through STEM debates is that STEM jobs are the jobs of the future (Andrews, 2015). The 2016 Global Economic Report cites STEM literacy as a yardstick of future preparedness of a nation. The suggested trend for the 21st century economy is to reach the penultimate label of being either "innovation based" or "knowledge based" (Schwab, 2011-2012, World Economic Report).

The World Bank (2014) report bemoans the under-research capacity on STEM education in Sub-Saharan Africa. The report outlines a demand for research, skills and education including STEM as an important strategy for Africa's socioeconomic transformation and poverty reduction. Among other things the report stated that improving the quality of higher education in STEM fields would benefit millions of youths entering the job market each year in Africa. Africa is the home to the largest growing school-age population globally, and with more than 60% of its population under the age 25 in Africa, and by 2050 one third of global youth will be in Sub-Sahara alone (Dews, 2019). That means Africa especially the Sub-Saharan Africa has a younger workforce.

On the role of STEM education in Africa, the future aspirations notably one (1), eleven (11) and fourteen (14) of the African Union agenda 2063 projects Africa nations to be amongst the best performing countries in global measures by the year 2063. These aspirations according to agenda 2063 could be attained through strategies of inclusive growth, job creation; increasing agricultural production; investments in science, technology and innovation, etc., including the development of human capital through sustained investments based on universal early childhood development and basic education. Commenting on the African Union 2063 agenda, an article published by the Centre of Mathematics, Science and Education Technology Education on Africa (CEMASTEA) was of the view that African countries can attain the vision lest they reform their current educational curricular so as to bridge industry and academia (Sichangi, 2018).

For a successful STEM integration into the Ghanaian educational system there is a need to look at the curriculum. STEM education curriculum should be the type that encourages students to be curious, wonder, think, play, question, and connect with the world around them, so they will be able to invent and contribute their quota to the society in which they live in (Bardige and Russell, 2014). The development of standards-based curricula and integration models was crucial for developing quality STEM education materials in K-12 education (NRC, 2013). The education

curriculum in Ghana to the contrary focuses mainly on theory lessons rather than imparting the relevant practical and professional skills needed in the job market. There is lack of vocational support and training facilities to make our youth entrepreneurs rather than job seekers (Sasa, 2018). This unfortunate situation has created a lot of unemployment in Ghana especially graduate employment (Boateng and Ofori-Sarpong, 2002).

Again, for successful STEM integration education there is a need for supportive systems. The supportive system includes the school district support and supportive administrative team that would support, guide, monitor and evaluate STEM integration education initiatives including STEM integration education pedagogy (McMullin and Reeve, 2014; Park, Byun, Sim, Han and Baek, 2016).

Equally important is the factor of teacher quality or well qualified STEM teachers. This also ought to be looked at as it can contribute to the success or derail the STEM integration education agenda. They lack the content knowledge as well as the pedagogical skills to teach STEM subjects (Eckman, Williams and Silver-Thorn, 2016; Umoh, Akpan and Udogwo, 2013; Ingvarson, Reid, Buckley, Kleinhenz, Masters and Rowley, 2015). Today the acronym STEM has come to mean an approach to learning that provokes the inquisitiveness, innovation, dialogue and critical thinking (Osei-Tutu, 2020), which requires a special skill on the part of the teacher.

Systematic continuing development of teachers should also be paramount. The aim of many professional developments is/are to equip teachers with resources and tools to help them implement high quality, effective instruction ((MOE, 2014).

METHODOLOGY

The study employed concurrent triangulation design which is a mixed method approach in which data collection is only one phase during which quantitative and qualitative data are collected and analysed separately yet concurrently. Purposive and snowball were the sampling techniques used to select participants for the study. The participants included teachers, parents, administrators/representatives, as well as governments officials. The sample size for the study was thirteen (13). Table 1 gives the summary of how the sample size was constituted.

Table 1: Summary of study sample size

Sample	Number
A STEM hub representative	1
A STEM facilitator/administrator for a private STEM organization	4
Government official in charge of STEM Education	2
Teachers	3
Parents	2
A Representative of Ashesi Design Laboratory	1
Total	**13**

The first item from Table 1 is the STEM Hub representative in Accra Central Library. This is followed by four (4) STEM facilitators/administrators from some of the private STEM integration organisations in Ghana namely STEMBees, GHScientifc, JA Africa and AU-NEPAD. Also included are two (2) government of Ghana officials in charge of STEM education in Ghana, three (3) teachers comprising of an integrated science teacher at Kaneshie Secondary Technical School, a STEM educator from STEMBees and a Statistical Education Statistics teacher from the University of Cape Coast, two (2) parents with one (1) from Nsaba Senior High, Agona Nsaba, whilst the other parent was from Nyarkrom Senior Technical High, and Agona Nyakrom and a representative from the Ashesi Design Laboratory of the Ashesi University. The instruments administered for data collection were a survey questionnaire items and a semi-structured interview. Both instruments were administered at the same time.

The Table 2 below provides the summary of participants' responses. The responses are quantified in percentages. In this study, six (6) items were considered as the kay factors in the implementation of STEM education in Ghana. These were Supportive systems, Curriculum, Qualified teachers, Teachers' Professional Development, Infrastructure and Monetary resources.

Table 2: Factors to successful STEM integration education in Ghana

Statements	Frequency	Percentage
Supportive systems	13	100.0
Curriculum	11	84.6
Well qualified STEM teachers	11	84.6
Teachers' professional development	13	100.0
Infrastructure	10	76.9
Monetary resources	11	84.6

As presented in Table 2, all respondents (13) representing 100% were of the view that supportive systems are an invaluable factor to be considered for a successful STEM integration education. The factor of supportive systems is very important. Supportive systems (include the school district support and supportive administrative team) are needed to monitor and evaluate the STEM integration agenda from time to time. Various research supports this assertion. For example, Bruce-Davis et al., 2014; Park et al. 2016, postulates that a supportive system is needed to help teachers to give what is best to their students and to successfully utilize STEM programs.

Of the two ensuing factors curriculum and well qualified STEM teachers, 11 representing 84.6% of the respondent think they are important factors also to be considered for a successful STEM integration education. Curriculum is the DNA of any educational sector. It is the curriculum that spells out how educational activities ought to be carried out. The call for a curriculum change corroborates with Sichangi, (2018) who advocates for the need for African countries to reform their educational curriculum in order to meet the African Union 2063 agenda on education. It is gratifying that the government of Ghana through NaCCA in 2019 rolled out the standard-based curriculum for KG to primary 6 pupils. The standard-based curriculum is a shift from the objective-based curriculum to standard-based curriculum with focus of strengthening the acquisition of the 4Rs- Reading, writing, arithmetic and creativity as fundamental for lifelong learning and national development. That is a shift from exams based to knowledge acquisition.

Well-qualified STEM teachers and teacher's professional development is indispensable. Looking at the current capacity of some educators we have, there is the need for us to be concerned. This is echoed by Umoh, Akpan and Udogwo (2013); Ingvarson et.al (2015), who stressed on the impact of teacher quality on students. Therefore, there was the need to look at how teachers are recruited, developed and trained.

Again, all the respondents (13) representing 100% also postulates that teachers' professional development is a crucial factor for STEM integration education. According to the data, a critical factor like infrastructure had 10 of 13 respondents representing 76.9% acknowledge it as a necessary factor, whereas 11of 13 respondents which amount to 84.6% of respondents think monetary resources is a key factor. Infrastructure and monetary resources are very important factors. STEM integration often requires a lot of cost to provide the necessary infrastructure as well as the logistics that will be needed (Nadelson and Seifert, 2017).

From the Table 2 above it can be seen that, factors such as supportive systems and teacher's professional development were the modal factors because they had the highest frequency of 13 of 13 respondents with a 100% for each, whereas curriculum, well qualified STEM teachers and monetary resources factors all had 84.6% respectively. However, infrastructure as a factor recorded the lowest percentage of 76.9%. In summary participants are of the view that supportive systems and teacher's professional development are the most important factors to be considered first, then equally important factors such as curriculum, well qualified teachers and monetary resources be given priority before infrastructure.

Twelve (12) of the thirteen (13) of the respondents were interviewed for further explanations. On the factor of infrastructure, a respondent put it into two components. According to that respondent, the first component is hardware whereas the second component is the software. The respondent asserts that:

> *"having the research centres, the STEM centres and buying the equipment (logistics), having the building and the space, (all the tangible hardware stuff) is the hardware. On the other hand, the software refers to human capacity building*".

Expatiating on the importance of the software aspect of the infrastructure, a respondent is of the view that

> "*the teachers would need a skill to be able to take certain content or concept and bring it alive, in a way that the students can really appreciate the teaching methods and the lesson plans, and the problem-solving skills*".

Respondents were of the view that when STEM centres, research centres, building and all the necessary equipment are provided, STEM integration education will be able to take-off smoothly. Equally important is the capacity building of the teachers who are on the field and those about to enter into the teaching field. This is because according to the respondents,

"basically, if we you look at the capacity of the teachers, then we need a lot of training to be able to work together and bring out this STEM education to a success".

This is so because some teachers are not confident themselves let alone their students. Also, it has been realized that other teachers especially in the rural areas according to a respondent

"are finding it difficult to go digital" or embrace modern technology.

Hence the clamour call

"*for reorientation of teachers"*

to be able to fully blend STEM contents in a way that will bring out the best in their students. On supportive systems, a respondent is of the view that

"there should be systems in place to make it work to ensure that the implementation of the STEM program succeed".

These systems would see to the monitoring and the evaluation of the STEM integration program. To be able to provide the hardware and the software components of STEM integration education, demands funding. All respondent asserted that monetary resources (funding) was a crucial factor to look at for a successful STEM integration education in Ghana. In view of this, one of the respondents specifically said there should be

"a budgetary allocation for STEM education".

On the issue of the curriculum, respondents were of the view that there is need for a shift from the exam-based curriculum to one that focus on practical activities. According to a respondent:

"If you look at our curriculum, it is exams-based curriculum, and if you look at the structure of STEM, it is how the child will be able to perform and bring out a project. So basically, if the curriculum is not changed from this exam-based structure, though teachers may go to learn the STEM education they may implement it partially, because when it comes to STEM they are looking at output of students, and the curriculum, if it is not changed to suit the STEM education, and if is still going to be based on what WAEC will set as exams to assess the students, then though the STEM will come, at the certain point in time they would shift from the intended purpose and become an exams-based education".

As already established, STEM education is basically about the output of students or based on what a child/student will be able to achieve at the end of the day, experiential learning so to speak. The focus of our education system should not be on certification. Instead, teacher training programs should do well to provide well-balanced skill development avenue where pre-service teachers will be taught to integrate the STEM approach in their teaching. The interest of students is also a very important factor. According to some of the respondents who raised such issue, government budget on education is constrained. Therefore, since not everybody is interested in STEM field but a few, there is a need to prioritize. In view of this a respondent said:

> *"it is just a number of students or group of people who are interested in STEM fields. Therefore, government should focus attention on these few ones rather than spreading it all over to save scarce resources.*

The issue about enrolment of students (class size) is also one of the major factors to consider. For a successful STEM integration education in Ghana, it is necessary to reduce class size. As one respondent put it:

> *"with STEM education, for the teacher to be able to work with the students, though it could be a team work, yet some students will demand attention individually. So, if the number of students per class is cut down and teachers will be able to handle them, then in that case it makes the implementation very easy".*

The methodologies of STEM integration such as problem/project-based learning, inquiry method, etc., all requires the teacher to facilitate. Although most often these methodologies take place in a form of group work, still the teacher may be required to give individual attention to certain students, hence class size, whether large or small can have positive or negative impact on the program. Furthermore, there is also a need to determine which STEM integration will best fit which institution as one size fit all STEM education does not augur well. Knowledge and application of STEM can solve major challenges of every nation be it education, agriculture, to name a few. So

> *"government can decide to say for health sector what kind of STEM education can we look into so that we can help support our health sector using STEM solutions. Same to agriculture, same to education so that once they consider that, then they look for technocrats or the experts who can help support that sector or aspect. The needs of one sector of an economy differ from the other. For example, if Ghana has implemented fully*

STEM integration education, then in this COVID-19 era Robotics would have been used to reduce the rates of infections at various health facilities. Also, if the country has considered doing virtual classrooms by now, we wouldn't be facing crisis as to when and how students should to schools and so on and so forth'.

Lastly there is a need for the country's universities both public and private to restructure its courses from the current state to one that focuses on STEM education, to serve as a continuation from the basic level for students who have the interest in STEM integration education. A respondent summed up this factor by bemoaning the inadequacy of STEM focused courses at our various universities in Ghana saying

"you see that most of our courses that is been offered in let say Universities, am speaking of any university but they are, most of the courses, they don't focus on STEM, they are only few courses. So fact forward if people finish school and you want them to go into STEM situation is difficult. So am thinking that government should try and restructure University system so that they will be able to offer courses that are focus on STEM. So that we can have more people interested. But if you have a lot of people not doing courses focus on STEM and just want to do our normal courses then we can't grow STEM education in Ghana". It is gratifying to say that Ashesi University has a specific STEM focused course called Design Thinking, and that is laudable.

In summary, the main factors to consider for successful STEM integration education in Ghana as outlined by respondents from the two data gathered are: supportive systems, curriculum, well qualified STEM teachers, teacher's professional development, infrastructure and monetary resources or funding.

Added on factors that popped up during the interviews that ought to be considered are the interest of students, enrolment of student in the classroom (class size), and determining which STEM activity is best suited for each organization. Bybee (2013), postulates that there are several models of STEM research. Moreover, enrolment of students in a class whether large or small can promote or derail the STEM integration agenda. So, if the number of students per class is cut down and teachers are able to handle them, then in that case it makes the implementation would be very easy. This is supported by (Umoh, Akpan, Udongwo, 2013).

CONCLUSION AND RECOMMENDATIONS

For STEM education to succeed factors including curriculum, supportive systems, teachers' professional development, infrastructure, monetary resources, interest of students, class size and determining which STEM activity is best suited for each organisation are necessary and sufficient conditions. Factors such as supportive systems, curriculum, well qualified STEM teachers and teachers' professional development needs immediate attention in STEM education. These factors are the levers. With these all the rest of the factors such as student's interest can be taken care of. With or without a STEM centre, if teachers are well trained and well resourced, they can still give a good STEM education. In view of this, there is a need for Heads of institutions to put in place a supportive system in their respective schools. The Ghana Education Service must ensure that well qualified STEM teachers are recruited into our schools. Heads of institutions must ensure there is continuous professional development of their teachers. Policymakers, administrators, and professional development facilitators must strive to help teachers develop understandings of and comprehensive strategies for STEM integration practices.

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