Chapter 28

A Review of Integrated Science Technology Engineering and Mathematics (STEM) Education in Africa: Implication for Revamping Science Education

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Abstract

The innovation that drives the economy of nations in the 21st century is found in Science Technology Engineering and Mathematics (STEM) education. Given this several studies have reviewed STEM education from different viewpoints or perspectives, however, it is very clear that probably none has explored this subject matter from the African perspective and determined whether this contemporary educational reform is a myth or reality. Hence, the purpose of this study is to review STEM education scholarly work in Africa. The study was guided by three research questions. The process of systematic review involved three phases: identification, screening, and eligibility. The finding shows the number of articles on STEM education published yearly by research methodologies across different countries. Articles with non-empirical methods are shown during the research period. The finding shows about 60% of STEM education contributions were made by authors from Nigeria, followed by South Africa (12.8%), Ghana (10.7%) Cameron (6.4%), Uganda, Kenya, and Zimbabwe 6.4%, 4.2%, and 2.1%, respectively. The number of articles using quantitative methods research methodologies than qualitative and mixed methods, among other findings. These findings have implications for rebranding secondary education in Nigeria. More research is recommended to focus systematic review on a global level.

Keywords: *STEM Approach, Secondary Schools, STEM Research Methodologies, and Systematic Review*

Introduction

The more recent Sustainable Development Goals (SDGs) acknowledge three critical dimensions to the development process: human development, economic development, and the environment. Education is a tool that helps to develop human capital for realizing these goals. Consequently, Science, Technology, Engineering, and Mathematics (STEM) Education has become a core emphasis of global perspective with the quest to improve science and technology, manpower, economic development, and self-reliance through a highly-educated workforce specifically through curriculum development. Although, it is skeptical if these goals have been successfully achieved particularly with the current crisis on self-reliance drive among African countries. With these, significant investments were made by many African countries in STEM education which is greatly propelled by concerns about prospective shortfalls in STEM-qualified professionals. National Governors Association Center for Best Practices, (2011), pointed out that, evolving job opportunities require STEM skills, it was also reported that 75% of the fastest-growing jobs require some level of mathematics and science knowledge and skills. STEM employees earn 11% higher salaries at all levels of education compared to their counterparts in non-STEM jobs.

Dugger (2010) opined that a nation's prosperity and economic independence depend on several factors, education is one of the important factors in a nation's wealth and success. Educational systems that are still relying on the traditional model of instruction will not be able to prepare their citizens to compete favorably and succeed in the 21st century. He further advocated for STEM education for all students will provide quality preparation for a future workforce that will drive innovation and compete favorably in the global market.

The system of education in African countries has the unprecedented task of initiating and implementing reforms in Science, Technology, Engineering, and Mathematics (STEM) and creating learning experiences that will groom students for meaningful varieties of STEM career fields in recently transforming and creating a generation who can think critically, innovatively and creatively (Ministry of Education, 2012). According to Riegle-Crumb *et al* 2012; Office of the Chief Scientist 2014). STEM education is an acronym meant to describe education or professional practice in the field of science, technology, engineering, and mathematics. Hernandez *et al*, (2014) opined that a firm STEM education is supposed to improve students' conceptual knowledge of the interrelated nature of science and mathematics, rather than literal knowledge to enable students to have a better understanding of engineering and technology. STEM teaching usually includes all activities related to education across all grade levels beginning from pre-school to post-doctoral levels. The teaching can either be in a formal setting, or an informal setting, sometimes both. As a yardstick for various emerging technologies, the role of STEM education is significant to the development of any economy in this 21st century. Stonhlmann et al (2012). It is believed that STEM education can boost students'

involvement in STEM-related occupations. Also, the literacy of students in science and technology can be accelerated around the world through STEM education. Integrated STEM education has a way of influencing the attitudes, interests, and achievements of students positively in school likewise motivating students toward learning (Talib *et al* 2018). Chew 2014 stated that students who engage and are masters in the four disciplines in STEM education have greater capacities to identify, solve problems, implements and integrate the concept they have learned into real-world issues. Stohlmann et al 2012 stated that higher-order thinking skills and technological literacy of students are usually developed via integrated STEM education bringing up students who are problem solvers, critical thinkers, innovators, and inventors. In low, middle, and high-income countries, STEM education is seen as a priority (Burnett and Jayaram, 2012; Ohize, 2017). Although in some parts of the world, STEM education is under development for example in Africa, where several low-income countries (LICs) are found. Hooker, (2017) Given to the progress in UNESCO Global Monitoring Reports, International Mathematics and Science (TIMS) research and the attainment of African students in mathematics and science is continually lesser than the international averages. Hence, the quality of STEM education is poor in Africa.

In Africa, the skills lagging are related to critical thinking communication, numeracy, leadership, and technical capacity decision-making. Although non-cognitive skills such as communication, leadership, and decision-making are comely crucial as economies transform. A survey of 83 employers was carried out by Burnett and Jayaram (2012) in Benin, Burkina Faso, Kenya, Senegal, and Uganda to determine the skills needs of employers. The result shows that employees with some university education and prioritized non-cognitive skills are preferred by employers. In the world today, both small and medium ventures prioritize cognitive over non-cognitive skills, while larger enterprise needs both. It was found out by the Association for the Development of Education in Africa that communication skills are essential and social skills are valued especially for young and new employees (Burnett & Jayaram, 2012).

Cognitive skills such as literacy, numeracy, and scientific literacy and other non-cognitive skills such as reliability and communication as well as some technical skills have been emphasized by the curricula for African countries in a survey. Although, direct links between schools and employers are weak (Burnett & Jayaram, 2012). The major threat to aligning education with the needs of employers is found in the policy of education and the lack of constant reforms to align education with the needs of society at a given time. It is important to highlight that integrated STEM education is the educational reform that aligns with the 21st century. It is assumed that the general education provided at the secondary level will lay the foundation for STEM education at the Tertiary level and manpower development that will contribute positively to economic development. Therefore, this review could yield meaningful insights that will reveal the state of STEM

education in Africa and Nigeria in particular. The findings could also have implications for revamping science and mathematics education in Nigeria

Statement of the problem

The involvement of students in the science and engineering field at the secondary school level and tertiary level in African countries has tremendously declined over the years as recorded by (Wilson and Mack 2014). More so, Phang et al. (2012) stated that despite the Stress on STEM, science, and mathematics a majority of secondary school students are not subjects of first choice hence their interest in science subjects has been continuously crumbling. According to the Ministry of Education 2012, the number of students taking science to arts subjects in the mid-1980s was a ratio of 31:69, this had lowered to 27:78. Ayob (2012) pointed out that the number of science stream students has dropped to 29% since 2012. The continuous decrease in the enrolment of students in a science discipline is not only ascertained in African countries but also at the international level as well.

The most reported reason for the sinking enrolment in various science programs is that students are disinterested in the way these subjects are being taught, Phang *et al* (2012) recorded that many students studying science find it to be boring, difficult, and not worth the effort. Even though STEM education has been carried out for many years now, most teachers claimed that they were less prepared to conduct STEM education in the classroom and teachers do not have an idea about technology in STEM education and how to combine this technology with science, engineering, and mathematics (El-Deghaidy and Mansour, 2015; Ashgar et al 2012). These problems show vast concerns that decreasing interest of students in science and mathematics may hinder the efforts to advance the innovations of technology to make African countries high-income countries in the future. Hence, this paper is to resound the importance of integrated STEM education in schools and also to emphasize the indispensable connection between STEM and economic growth.

Research Questions

1. What research methodologies are employed by African countries in STEM education?
2. What are the STEM approaches employed by African Countries?
3. What are the distributions of STEM studies among African countries across continents?

Research Methodology

Methodology

This section will discuss methods of choosing and collecting articles related to the keywords of this study: self-beliefs and motivation in mathematics. The review and analysis of this study were performed systematically at three electronic databases namely

Scopus, Google Scholar, and My Jurnal. The process of systematic review involved three phases: identification, screening, and eligibility which will be discussed further in the next section.

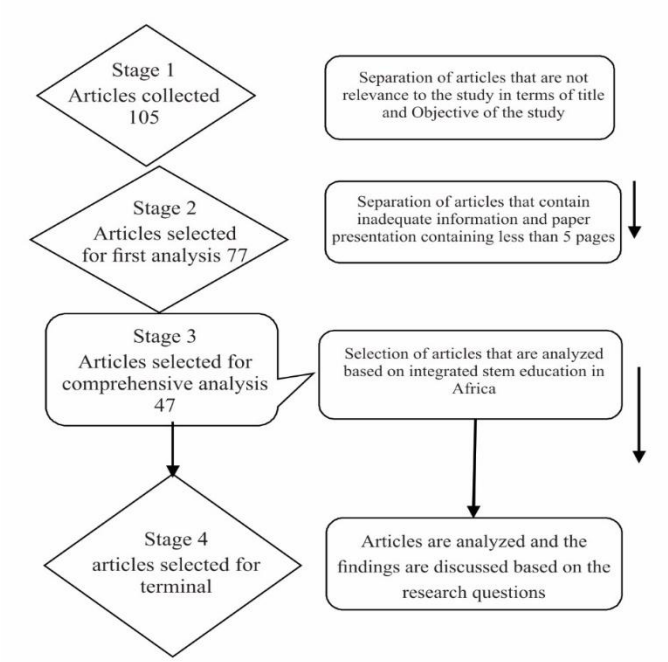
Data Source

Articles selected are searched in the main database, Scopus since the quality of articles published in Scopus is guaranteed. Only peer-reviewed articles are published in Scopus. Scopus published a wide range of articles from various fields and subscribed as the main database by more than 3000 institutions. Additionally, the researcher also conducted articles searching manually at different databases such as Google Scholar and My Jurnal for articles related to self-belief and motivation in local context based on the title, abstract, and keywords of the articles.

The literature review on this topic is set to achieve the objectives/research questions concerning integrated STEM education in African countries. The research method for reviewing the literature was adapted from the work of (Sultan 2015; Davide, *et al* 2014). This review employs three phases which include data collection and screening, data analysis, and evaluation. The first phase involves the retrieval of relevant articles and journals on STEM education in African countries, the Google Scholar engine was queried in February 2020, with related keywords such as STEM, Integrated STEM, STEM Education in Africa, and Teaching Integrated STEM Education. While searching for these keywords, the emphasis was given to STEM education in secondary schools STEM Education, African Countries, Integration, and Developing Countries: since STEM education has received a great increase with the emergence of Innovations and technologies. (Edosomwan, *et al* 2011). The search was limited to the span from 2012 to 2020. The search extended till the researcher could not find new articles in the collected articles set to confirm that the researcher reached a relatively complete demographic of the relevant articles.

Firstly, the researcher collected about 105 articles. In the first step of selection, the researcher selected 77 papers by examining their titles of them. The researcher rejected articles because the titles seem irrelevant to the objective. Then, in the second stage, another screening was conducted in terms of book reviews, panel discussions, and paper presentation which contain less than 4 pages, thus seems to have inadequate information, the researcher then arrived at 47 papers in the third stage. After the third stage, more in-depth document analysis was carried out by focusing on papers with only integrated STEM education in African countries that were able to answer the research questions, from the results of the selected articles, the researcher arrived at the fourth stage with 28 articles for the final analysis. The articles were analyzed and summarized according to the research questions and are represented in Table 1 and Table 2 below;

Stages in this Review



A detailed list of relevant articles has been analyzed under 3 subheadings based on the research questions.

Results and Discussion

In the following categories, the researcher reports findings as related to each of the research questions.

The research methodologies employed by African countries in STEM education over time?

To address research question one, the researcher classified all 47 publications including journals, articles conceptual papers, and literature reviews for different African countries about (1) quantitative methods, (2) qualitative methods, (3) non-empirical methods, and (4) mixed methods. The researcher assigned each article to a different method used in the study, backing it up with the process used in the IJ-STEM review (Li *et al*, 2020). Where there was more than one method used in the study, a decision was made by the researchers in choosing and assigning a method. After assigning all 47 articles, a final decision was reached.

Figure 1 shows the number of articles on STEM education published yearly by research methodologies across different countries. Articles with non-empirical methods are shown in a different section. Notwithstanding, the number of articles increase during the research

period in each of the four (4) sections, there were more articles with empirical studies than those without. The number of articles using quantitative methods increased greatly in recent years for those with empirical studies, subsequently by qualitative and then mixed methods. Although the number of articles with non-empirical studies such as conceptual papers or theoretical, and literature reviews is quite many during the research period, in this category, the number of increasing articles was noticeably less than the empirical studies.

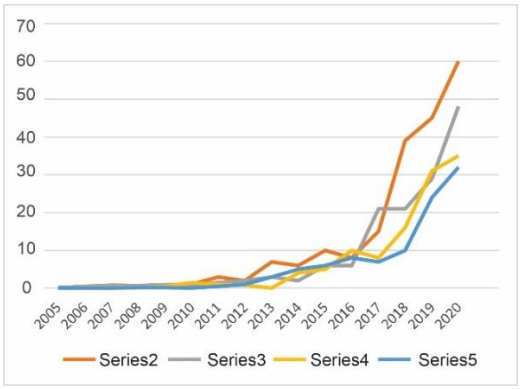


Figure 1 shows the article distribution of the research methodologies employed by African countries over the years. (Note; 2—qualitative methods, 3—quantitative method, 4—mixed method, and 5—Other method).

Figure 1 shows the distribution of research methodologies employed by researchers between 2005 – 2020. The findings show that most of the studies in this population were qualitative with about 60% publications employing qualitative research methodologies. Similarly, about 50% of the studies employed quantitative methodologies, while mixed method and non-empirical or others not specified were slightly above 30% each. It is important to highlight that between 2005 and 2009 most of the studies were mostly quantitative. These findings indicate that qualitative and quantitative research methodologies are more common in this population.

STEM approaches employed by African Countries

To address research question 2, the researcher generalized the findings into three approaches that have been employed by African countries for successful STEM integration.

1. **Curriculum and Assessment**: This refers to approaches to curriculum development in terms of content, skills, and teaching approaches/strategies. As a means of strengthening both the relevance and accessibility of STEM education, a constructivist approach to curricula has been adopted, using strategies such as design-based learning, interdisciplinary approaches, collaborative instructional approach, and project and problem-based learning, among others.

2. **Individuals**: This approach is concerned with strategies deployed to address issues of recruitment, deployment, professional development, and retention of suitably qualified personnel in secondary STEM education. These strategies comprise improving teacher status, increasing recruitment to teacher training programmes, and Continuous Professional Development) initiatives to improve classroom practice;

3. **Material Resources**: This approach deals with policies and initiatives devised to improve infrastructure in secondary schools to support STEM education. Strategies to improve textbook quality and distribution, access to specialist science equipment, and ICT capacity in schools are reviewed.

Distributions of STEM studies among African countries across continents

Table 1 shows the distribution of STEM education among the top 7 African countries in terms of the number of publications. About 60% of STEM education contributions were made by authors from Nigeria, followed by South Africa (12.8%), Ghana (10.7%) Cameroon (6.4%), Uganda, Kenya, and Zimbabwe 6.4%, 4.2%, and 2.1%, respectively. The results also revealed that the patterns are relatively consistent over time.

Table 1 Distribution of STEM education among the top 6 African countries.

Rank	Country	Frequency (%)
1	Nigeria	28 (59.6%)
2	South Africa	6 (12.8%)
3	Ghana	5 (10.7%)
4	Cameroon	3 (6.4%)
5	Uganda	3 (6.4%)
6	Kenya	2 (4.2%)
7	Zimbabwe	1 (2.1%)

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Implication for Revamping Education

Globalisation, technology, international competition, changing markets, and political challenges create new urgency to develop the skills and knowledge students need to

succeed in the 21st century. These skills and competencies can be acquired through an integrated STEM approach to instruction. Consequently, there is a need for revamping education or a need for a paradigm shift from teaching science and mathematics subjects in isolation to an integrated manner, a shift from teacher-centered to learner-centred. Hence, there is a need for teacher capacity building on how to facilitate meaningful learning in the classroom and to link science and mathematics learning to real-life situations. Nigeria's quest for Vision 2030 and sustainable development will be a mirage without the appropriate teaching and learning of science and mathematics. Educational stakeholders must as a matter of urgency stop the leap service on education and embrace the integrated STEM education reform. There is therefore a policy reform for teaching and learning that will align with the skills needed by employers in the 21st-century.

Conclusion

The systematic analysis of articles that were considered to be in STEM education in about 37 selected journals shows tremendous growth of STEM education in African countries. From the analysis, it shows that over the past 10 years STEM education research has been highly recognized as an essential subject area and research was being published across various journals in different African countries. Although researchers still hold varying views on research methodologies employed in STEM education, quantitative methods are mostly used. Moreover, the systematic analysis shows a striking increase in the number of STEM approaches that African countries have adopted to integrate STEM education successfully in secondary schools. This attainment may mark an important milestone as STEM education is seen as very essential for maximum learning for children in African countries. The researcher anticipates that STEM education continues to develop across African countries to support educational initiatives and programs in STEM worldwide.

Recommendations

Given the findings of this review, it is recommended that more educational research is needed in the area of STEM-based approaches to classroom instruction. Mixed method research methodologies are recommended to give a robust understanding of the effects of STEM education on enhancing 21st-century skills.

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