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Evolution of STEM, STEAM and STREAM Education in Africa: The Implication of the Knowledge Gap

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Abstract

Developing countries have limitations in almost every area of modernization. These limitations are not limited to only education and the classroom in which teachers and learners exercise their duties but also other aspects of human endeavors. Scholarly approaches embraced by educators in the quest to evolve knowledge, especially those whose basis arises from Science and Mathematics, have generated considerable improvement over the years. These approaches beget a pattern aimed at preparing emerging learners with up to date knowledge on how best to solve challenges required of complex yet everyday human life. The goal of education and, by extension, science is to equip citizens with the requisite skills to embrace challenges and solve everyday human problems. This article exposes the trend in STEM, STEAM, and STREAM approaches, as well as the rationale for each of the appendage components of the evolution. The global application of robots in areas with a shortage of manpower is a trend in the global economy and governance. Africa's classroom integration and limitation of technology in classroom learning can potentially be resolved with solutions from robotics. A measure of the grounds covered in the developing countries and the gap expected to be covered were extensively explored. The limitation in knowledge, expertise, and resources to cope with these emerging trends for purposeful and meaningful classroom integration in Africa were investigated.

Keywords: *Evolution, STEM, STEAM, STREAM, Knowledge Gap.*

INTRODUCTION

The evolutionary nature of man presents modern challenges in various aspects of human existence. Disciplines and fields in the sciences are inter-dependent and indispensable structures of a bigger puzzle aimed at solving daily human challenges. The architecture of each problem is embedded in disciplines whose sole purpose is to resolve this peculiar anomaly. The knowledge of science may be viewed as a way of investigating or process, and a pattern of inquiry with the ultimate purpose of making meaning of the natural world (Abimbola & Omosewo (2006). Science as a field of study investigates nature based on facts learned through experiments and observation. Science Education can be seen as learning science by acquiring and developing conceptual and theoretical knowledge through scientific inquiry and problem solving (Obeka, 2011). The product of scientific observations and experiments are presented theoretically as principles and laws. The utilization of these theoretical facts and their application can be found in the field of Technology, Robotics, Engineering, and Arts. All of which are Mathematically embedded.

Technology is often viewed as the usage of science in industry, engineering, and beyond to invent useful machines and pieces of equipment capable of solving daily life problems. The aggregation and application of the knowledge of science and mathematics in the understanding of the sources of energy to resolve human limitations may be regarded as engineering. Similarly, engineering may also be viewed as a work of design and creation of a large structure or new product or system by using methods aboriginal to science. Mathematics also relates to sciences and includes algebra, geometry, calculus, and many more.

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It concerns the study of number, quantity, shape, and space and their inter-relationships by using a specialized notation.

Science, Technology, Engineering, and Mathematics (STEM) was formerly referred to as Science, Mathematics, Engineering and Technology (SMET) originating from National Science Foundation (NSF) (Sanders, 2009). Historically, STEM implementation was profound in the business world, ushering the industrial revolution, which saw Thomas Edison and several inventors alike evolve STEM education outside the classroom. STEM application then was significant in the field of engineering, leading to the manufacturing of light bulbs, tools, and other machines. STEM approach aimed at providing students with critical thinking skill that promotes creative problem solving, as well as, qualitative workforce for self-reliance. The perception of researchers on STEM education is that learners would benefit even when they don't pursue post-secondary education or/and would benefit more if such students attend college, particularly in STEM related field (Butz, Kelly, Adamson, Bloom, Fossum, & Gross, 2004).

Thomas Edison and Henry Ford were informally educated before their inventions (Beals, 2012), predating STEM education in the classroom. These inventors applied the knowledge and principles of STEM to bring about evolutionary trends in physics with their invention; nonetheless, STEM education was not taught in the formal educational setting at the time. White (2014) posited that the introduction of STEM education was necessitated as a result of several events that took place before 1862. The Morrill Act of 1862 propelled several pieces of training in the field of agriculture, science, and engineering. These events were revolutionary as it brought about the advent of several universities. These universities served as a platform for many inventions of today. Also, the second World War, as well as the Soviet Union's launch Sputnik defined what was later referred to as STEM (Butz et al., 2004). World War II, and the launch of the Soviet Union's Sputnik, historically boosted STEM education across the world.

STEM Education

STEM was once referred to as Science, Technology, and Society (STS) in the distant past. Its emergence in the classroom is to train individuals with up-to-date knowledge in the affiliated disciplines to meet the current demand of the society and to shift the limit of human thinking and problem-solving ability, which may result in meaningful development and improved living. Historically, Science, Technology, Engineering, and Mathematics, predates its classroom teaching. Its application also existed before formalizing the approach in classroom learning. Each of these fields and disciplines by affiliation is now being studied from the most elementary stage of classroom teaching to the highest level of formal education in the developed world. Although STEM education still remains a challenge to some developing countries in Africa.

The comprising fields of STEM and the afore-stated perspectives are popular and are established in descriptive terms in STEM disciplines, although, while there are various fields than the stated positions. Science and Mathematics form the basis for which STEM education is built. Fields of STEM have the widest tributaries in academia with the most profound impact. Despite the direct application of the knowledge of science and technology the world over, there are reports that limited resources are garnered to ensure continuous development in the field of STEM, especially in developing countries. This position is predominant in the primary and secondary tier of education (White 2014).

For educators, STEM may be viewed as the integration of Science, Technology, Engineering, and Mathematics as a single unit of knowledge. These various disciplines are resources for learning and invention and are seen as relevant, significant, and inert-related. Education in STEM as a trans-disciplinary field is old, but the knowledge integration may serve as a resource to enrich learners and make sense of the world rather than observing through narrow inter-disciplinary lenses. STEM education could still be said to have challenges which are not only students related, rather, peculiar hindrances encountered by teachers of STEM in developing countries (Adeyemo, 2010).

In the developed world like the United States of America, efforts have been put in place by government and relevant stakeholders to foster STEM education. These efforts emphasize the importance of science and engineering, their knowledge and practices, as well as the promises for solving future human challenges (National Research Council, 2012). Also, the United Kingdom engaged a nationwide network for STEM through STEMNET. In Singapore, science coursework emphasized reasoning inventively with the mindset of coming up with solutions to existing problems and/or future problems (Singapore's Ministry of Education, 2012 & 2014). The Korean government has also reported similar effort aimed at driving the integration of school science with other disciplines through Science, Technology, Engineering, Arts and Mathematics (STEAM) education (Ministry of Education Science and Technology, 2011).

STEAM Education

Arts is a field of study which embodies the practical representation of emotions, bringing to the reality of imaginations, making meaning of habits, developing the human mind to evoke evolution in the manner and approach which are non-existent or an improvement from existing knowledge. The application of knowledge in arts helps elicit emotional awareness. Arts enable students to discover humanity and nature (Eisner, 2008). Scholars have alluded to the need for integration between the knowledge of science and arts to evoke spontaneous creativity, especially in the 21st century. The evolution of models and designs in engineering and science defines the importance of arts in bringing about satisfaction essential for nowadays citizens (Feldman, 2015; Piro, 2010). Countries like the United States, Korea, and China began the production of STEAM curricula for their respective nations immediately the need arose, although, over a decade ago (White, 2010). Science educators recognize the limitations in the development of students' higher-order abilities, which may hinder collaborations in the Arts-learning areas to bring about interdisciplinary expression of STEAM curricula (Sousa & Pilecki, 2013).

The transformation of STEM to STEAM was a movement among researchers and educators. The resultant addition of Arts to STEM was rooted in years of development in various aspects of STEM education, brought about as a positive way of improving on the existing knowledge to bring meet the needs of the 21st-century citizens. The introduction of Arts was a paradigm shift as the conscious use of skill and creative imagination, especially in the production of aesthetic objects and improved phase of design, became the new order in human problem-solving evolution. The possibility exists that STEM may have left a gap many employers of labor are eager to fill. The creativity to stimulate the interest of consumers in a competitive economy requires a paradigm shift from the already saturated market. The gap earlier enumerated requires the evolution of the existing framework of science, technology, engineering, and mathematics. Hence, the infusion of Arts in the training and development of students/learners to thrive in the present and rapidly approaching future careers. STEAM framework aggregates the knowledge of Science, Technology, Engineering, Arts, and Mathematics as a template to foster students' mode of inquiry, critical thinking, and problem-solving skills. Practically, experiential, teamwork, creativity, and problem-solving abilities of learners are skills required of innovators of this age (Taylor, 2016).

STEM expectedly delves into the four-constituting fields. The limitation of students in STEM programs is more of practicality and competitiveness, which are non-existent/limited to Science, Technology, Engineering, and Mathematics. The economic demands of nations in this age requires more than the existing framework of STEM (Boy, 2013). The application, creation, and ingenuity in STEM-related fields are also significant components aimed at solving life's daily challenges. STEAM introduced a different dimension to how STEM education is being approached in the classroom. Arts brought diversity into the package before the robotics era. Invariably, STEAM avail students the opportunity to relate their experience in STEM areas to arts components. STEAM could be said to have replaced its predecessor with vastness, critique, inquiry, and innovation (Taylor, 2016).

Early researchers in STEAM education studies reported ground-breaking success in the implementation of the curricula in the United States. Further reports on learning activities which involves the integration of science, technology, and the arts recorded positive difference in engaging low performing students, resulting in improved performance and competencies (Clark, 2014; Stoelinga, Silk, Reddy & Rahman, 2015). STEAM education is not alien to STEM education, but an expanded scope of STEM education. The curriculum of STEAM emancipates science educators towards the domestication of the curriculum fit the immediate needs of the society (Holm, 2011). STEAM education transforms students learning experience based on five interrelated and inter-disciplinary approaches to knowledge i.e., relational, experiential, cultural, critical and visionary, and ethical (Taylor, 2015).

STREAM Education

STREAM education may be viewed as a unique approach to instruction, which brings together the approaches of science, technology, robotics, engineering, arts, and mathematics into play for a classroom experience. The technology involved in the design, construction, and operation of robots in an automated form is robotics. It is evident that students view robots as interesting both in real-life situations and virtual encounters, as such, an effort to integrate them into STEAM education should not be totally alien (Eguchi, 2014). The era of automation and robotics is already here. The use of Artificial Intelligence (AI), Virtual Reality (VR), and Augmented Reality (AR) are areas that have significantly improved medicine and surgery through simulation of surgical procedures and minimally invasive surgeries. Also, self-driving cars in automobile industries, automated space crafts, and drones are also possible as a result of the advancement in robotics. These strides are not limited to the aforementioned field but all across human relations and interactions. Although, STS, STEM, and STEAM have already existing curricula, unlike STREAM. Expectedly, this learning approach is non-existing as scholars have argued robotics to be a field under engineering. This view may be viewed as myopic. The components of robotics (Machine Learning, Artificial Intelligence, Data Mining etc.) have a limited foundation in the field of engineering.

It should be noted that STREAM at the elementary, basic, and post-basic level of education in developing countries may represent the required catalytic push for future learners in the emerging field of robotics both in the developed and the developing worlds. STREAM students are expected to invent, create, design, and solve problems. Students with the ability to discover themselves may be afforded the opportunity to improve with this approach. As educators, various scenarios should be provided to students to experience instances that allow for self-discovery. To self-discover, learners have the option of making mistakes, employ several means to solve such problems, brainstorm on the new idea on the best approach and how best to apply it to real life situations having an encompassing mindset from STREAM. The introduction of Robotics into the classroom teaching at both basic and post-basic levels of education is gaining momentum in the developed world. Robotic innovations are a strong indication of how much popular attention robotics technology has garnered over the years.

The year 2013 ushered a new paradigm in the delivery of goods. Amazon, the world's biggest delivery franchise, introduced robots in the sorting and delivery of their services. At about the same time, Google also acquired eight robotics companies, which included Schaft Inc., Boston Dynamics, and others. DARPA, trialed in December 2013 a robotics competition with its grand finale in December 2014. Recently, Softbank Mobile and Aldebaran Robotics, a Japanese and a French company, synergized in 2014 to unveil the world's first humanoid robot called Pepper. The robot (Pepper) functions as a human assistant by reading and responding to human emotions, a giant stride in robotics at the time (Friedman, 2015). A

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humanoid robot was used for educational purposes by Aldebaran Robot. This programmable robot proved useful in the development of an algorithm for children with Autism.

The emergence of the novel Coronavirus (Covid 19) in December of 2019 established the gap in human planning and reality. At the same time, the immediate economic impact of the pandemics was inestimable. The future impact on all human activities still lingers. In most developed and developing worlds, education was at a standstill like many other sectors. The death recorded globally is rising. Health workers are losing their lives, along with many other citizens in various disciplines. The shortages have been recorded as a result of the pandemic may be remediated through the production of a robot capable of performing human functions to consolidate the effort of the humans available. However, robots are being deployed to assist in a number of countries in Asia (China, Singapore, India, Taiwan, and Japan) and a few countries in Europe. Countries with this capability have a different approach to educating their citizens in robotics and enjoy a different curriculum to nations.

The gap between STEM, STEAM, and STREAM Education in Africa

Technology is ubiquitous, and its integration can be felt in every aspect of human lives, both in Africa and beyond. Students of this age are digital natives and have preferences for smart and automated devices. At the moment, Africa is a major consumer of technology, the implication is that a significant amount of her economy is drained to America, Europe, and Asia, owing to the purchases of useful but foreign technologies. A continent with the majority of her countries regarded as developing needs a change of approach and curriculum. In Nigeria, for instance, 90% of technologies used in the country are imported (National Office for Technology Acquisition and Promotion, 2017). The consequences of nonchalance to STREAM education in Africa is a great danger to the continent as monies spent on education in foreign lands by Africans is enormous. This is a pointer to the depleted state of education on the continent, which requires urgent attention by all and sundry.

Several kinds of research in robotics have surfaced in recent years (Benitti, 2012). It could be said that the progress made so far in robotics has been geometric in the recent past. The application of Robotics technology has impacted a variety of fields and disciplines. These impacts can be felt in medicine, physiotherapy, gaming, home, and office appliances, search and rescue missions, automobile, space exploration. Interestingly, none of the afore-listed impacts is against the belief of the African nation, but this strive and zeal for change seem absent at a time when the developed world is not waiting to be caught in the wheel of development.

Evident from table 1, the shortfall experienced by the education sector in the national budget of Nigeria could be termed as alarming. The United Nations directives on education are far from achievable in most African countries. The national budget for education in Nigeria is less of the desired since independence, and this is a perennial situation in most African countries. The implication of this carelessness is alarming. This could be a consequence of why science education and it modern applications are not met or surpass in terms of expectations by many African countries.

Table 1: Budgetary Allocation to Education from 2016 to 2020

Year	*Budgetary Allocation to Education*	*% allocation to Education*	*Nigeria Budget/year*
2016	N369.6billion	*6.01*	*N6.1trillion*
2017	N448.01billion	*6.00*	*N7.3trillion*
2018	N605.8billion	*7.04*	*N8.3trillion*

2019	N620.5billion	*7.02*	*N8.83trillion*
2020	N691.7billion	*6.70*	*N10.27trillion*

Budget office of FRN. budgetoffice.gov.ng and nationalplanning.gov.ng Retrieved 22nd May, 2020

For a society to be adjudged developed, its sophistry in the fields of science and technology come to bear in determining the level of awareness of citizens in such a society (Adegun, 2003). If the required commitment from the government and other relevant stakeholders is given to modern classroom approaches like STREAM, such effort could catalyze improvement, which may bring about positive socio-economic well-being of citizens. The Nigerian Educational Research and Development Council (NERDC) has, among other prerogatives to design a curriculum for senior secondary school science. The objectives of NERDC, among others, is to afford citizens basic literacy in science and technology for functional living and to imbibe necessary scientific skills and attitudes (FRN, 2013), to this end, all effort should not be spared to attain this modernity by concerned developing countries.

Several educational movements have advanced the course of robotics in the classroom in recent years, although, in the developed world. Educational innovation, like coding education for primary and secondary students, is common place in the United States, Japan, Korea, Singapore, Canada, and several other European countries lately. Eguchi (2014) reported the effort of the U.S. Computer Science Educators in 2013 brought coding into the fore of classrooms around the world, this effort was tagged "Hour of Code". Consequently, millions of students from countries all over the world participated in an hour of coding between December 9th - 15th, Code.org reported. One out of five U.S. students took part in the exercise. More female learners participated in the United States schools than in all of the past years (Code.org, 2013). The exercise, as reported, encouraged millions of participants and served as a panacea for the integration of coding in primary and secondary schools. These feet are also attainable in the developing world for onward integration and development.

A new curriculum was birthed in the United Kingdom in 2013. This curriculum aimed at integrating engineering and coding in the elementary stages of their education (Department of Education, 2013). The framework reads, "we aspire to an outcome where every primary school pupil has the opportunity to explore the creative side of Computing through activities such as writing computer programs". At elementary, pre, and post-basic levels of education, an enabling environment was encouraged for learners to learn robotics and engage in web-based activities. Learners were admonished to seize make use of the available opportunity to excel at their career choices, especially those willing to pursue STREAM-related carriers (Royal Society, 2012). The introduction of computers and its affiliated applications, especially at the primary and secondary level, may give learners the upper hand in machine learning, data mining, programming, digital marketing, and other futuristic opportunities of today's world. This is also a compliable initiative for developing counties in Africa.

CONCLUSION

The evolution of STEM to STEAM positively impacted the related fields and disciplines immeasurably. The excitement students borne from the introduction of STREAM in the classroom presents yet another reason for their willful look into the future with hope and excitement of the possibility of new knowledge to acquire. Notably, a greater percentage of the current workforce never had the opportunity to be prepared in the classroom of what is currently required to survive in the present work environment, most had to adapt to stay relevant and competitive. STRAEM education affords present students a glimpse of what is required of their future carriers. Although, the challenges of building the capacity of the present educators to cope with this knowledge area remain germane for the success of STREAM education, especially in Africa.

During the designing, construction, coding, and documentation of automated robots, learners can experience the inner working of these technologies and apply the skills and content learned in a school outside the classroom environment. Robotics is a large field of study which, if properly harnessed, can form rewire the approach, teachings, and learning of not only STAEM but other disciplines alike. The knowledge in robotics may afford learners the template to foster collaborative skills, team application of a technological tool for problem-solving, and boaster critical think skills. Robotics in education can serve as a learning tool to accommodate experiential learning through hands-on and mind-on educational resources. Similarly, an engaging learning environment as obtained in STREAM approach could improve students' skill set to accomplish any task of their interest.

Recommendations

Among others, African leaders and relevant stakeholders must;

1. Commit a significant amount of their budget to science education and its approaches in a bid to improve the state of technological development on the continent.
2. Embrace and encourage local entrepreneurs whose products/instructional resources are in the field of STREAM education.
3. Engage science educators in training and capacity building to update their knowledge of what is obtainable outside the continent knowledge and technology.
4. Improve the state of classrooms, laboratories, and school facilities to attract interested students.
5. Adequately take care of educators as a means to encourage carriers in the fields.
6. Upgrade educational and community resources outside the school environment to the gap between formal and informal environments.
7.

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