STEM Education: A Tool for Sustainable National Capacity Building in a Digital Economy

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Abstract

Currently, Nigerian college students rank low among students of both the industrialized and developing countries when it comes to achievement in Science Technology, Engineering and Mathematics (STEM). This is a fact borne out in test scores and other assessments of academic achievement in various examinations. This paper defines STEM as an educational taxonomy used in the context of multidisciplinary domain when addressing educational policy and curriculum choices in schools to improve competitiveness in science and technology development. The perspective in this paper shows that STEM has implications on the workforce development, national security concerns and other related policies. In this paper, STEM definition as it relates to the new digital economy and knowledge era for national capacity building is presented. A modified framework for STEM education (M-STEM) from primary to tertiary level in Nigeria is proposed while articulating its merits. Best practices in M-STEM initiatives including programme implementation, sustainability and professional developments are discussed. The paper concludes by articulating the open challenges while discussing the remediation.

Keywords: *Economy, Capacity, Workforce, Sustainable, Development.*

1.0 Introduction

Science, Technology, Engineering and Mathematics (STEM) education is a global concept that encompasses the processes of critical thinking, analysis, and collaboration in which students integrate the processes and concepts in real world. This is aimed at fostering the development of skills and competencies for career and life generally. This global concept is seriously affecting the quality of most Nigerian college and university graduates.

In Nigeria today, student's performance in STEM subject areas remains a worrisome nightmare to stakeholders in the educational sector. Alarming statistics has continued to reoccur on yearly basis. For instance, the West African Examinations Council, WAEC, results statistics of May/June, 2015 showed that achievements in STEM subjects are less than 50% average [1,2]. Interestingly, for several years, educational policy leaders have been working to strengthen STEM education throughout the states in Nigeria with little success rate.

The immediate goals of STEM education are to increase the proficiency of students in STEM and increase the number of students who pursue STEM careers in advanced studies. This is because STEM occupations remain influential in driving economic growth and innovations [3]. From the reports of the Program for International Student Assessment (PISA), which provides cross-country comparisons in member and non-member nations of 15-year-old school pupils' performance on mathematics, science, and reading, Nigerian students ranked zero as they were not captured in the ranking [4]. Consequently, to remain relevant in today's digital and knowledge driven era, a Modified STEM (M-STEM) education is advocated for in the Nigeria context. This will serve as a veritable tool for sustainable national capacity building starting from the elementary to tertiary levels.

This paper is organized as follows. Related definitions and perspectives on STEM and brief discussion on the STEM strategy and educational reform in Nigerian are presented in section 2. Section 3 presents the M-STEM framework while capturing its best practices. Section 4 discusses the open challenges while section 5 presents a comprehensive remediation. Section 6 summarized and concludes the paper.

2.0 STEM Definitions & Strategy in Nigeria

Tsupros defined STEM education as an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons [5]. He explained that STEM education is a model of learning that calls for rigorous academic concepts which are coupled with real-world lessons for practical application. Morrison in his work [6] explained that STEM which is the integration of the four disciplines into one cohesive teaching and learning paradigm is aimed at removing the traditional barriers erected between the four disciplines in STEM. Brown, et al [7], defined STEM education as a standards-based, metadiscipline residing at the school level where all teachers, (especially science, technology, engineering, and mathematics teachers), use an integrated approach to teaching and learning. Study by Okpala[8] carried out an extensive discussion on STEM education in USA, China and Finland while highlighting various reform perspectives.

From the above definitions, this paper defines STEM as an educational taxonomy used in the context of multidisciplinary domain when addressing educational policy and curriculum choices in schools to improve competitiveness in science and technology development for the benefit of humanity. In this work, both STEM and Modified STEM will be used interchangeably just to convey the related concepts in the most simplified form.

There have been various strategies for STEM initiative in Nigerian. Okpala, [8] discussed the key issues from Nigerian STEM reforms. These include government policies on STEM using the National policy on education which took care of primary, secondary and tertiary curriculum. The identified methods of policy implementation include the Basic Primary and Secondary Implementation, STEP-B (Science Technology Education Post Basic) Project and the Tertiary Education Trust Fund (TETFund). Despite all these interventions, there are still latent problems in producing STEM graduates. Also, with the expected STEM job growth of over 17% between 2016 and 2020, there is yet no result oriented, sustainable scheme to develop the needed workforce that will take up emerging job opportunities starting from the elementary to the tertiary levels.

3.0 Sustainable Development with STEM

STEM could be used as a veritable tool for the realization of a digital economy and its sustainability. According to WCED, Sustainable Development (SD) is defined as the development that meets the needs of the present without compromising the ability of future generations to meet their own needs [9]. Looking at STEM as it relates to the new digital/knowledge era for national capacity building, SD with STEM requires meeting the basic needs of humanity and extending opportunities for economic and social advancement. Hence, STEM remains a positive force for sustainable development by providing new ways of solving immediate societal problems. In this regard, education is one mechanism through which many SD objectives might be realized in this knowledge era. Figure 1 shows a pictorial description of the elements and concepts of SD. Without STEM, SD remains a far reaching illusion.

Consequently, several organizations are working towards improving the digital economy via communications networks and information availability. The United Nations Sustainable Development Network (SDN) [10] is one example of how modern information technology can be used to assist developing countries maintain and apply data for domestic development activities. STEM remains the key driver in such initiatives.

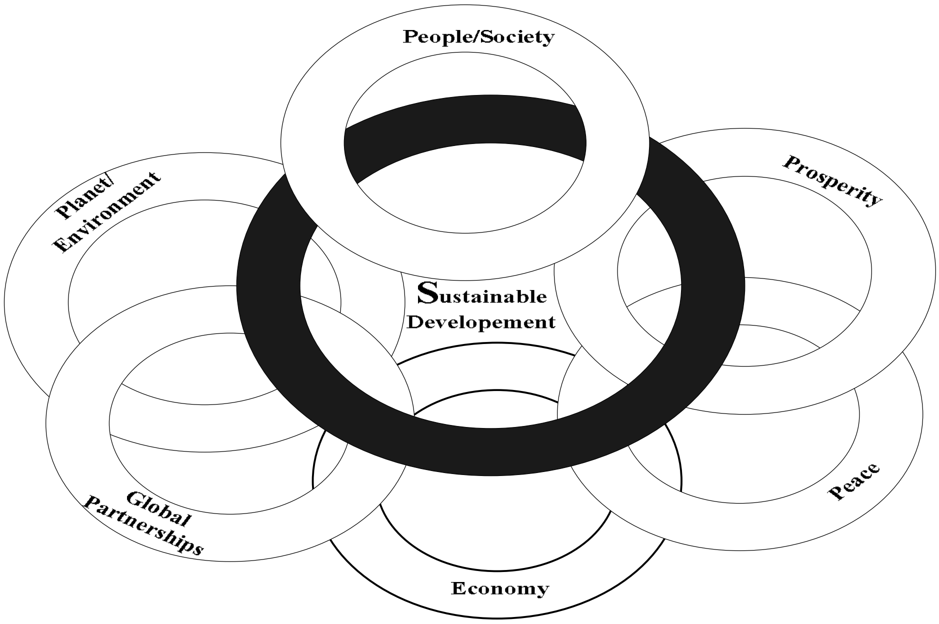

Figure 1: Sustainable Development Concepts

3.1 STEM versus Digital Economy

Digital economy basically refers to an economy that is based on advanced digital computing technologies which supports free flow of information anywhere, anyhow and everywhere. It is the new Internet of Things (IoT) economy leveraging the web platform. Its role in accelerating globalization has been strongly felt in the knowledge era. The digital economy has three main conceptual components as identified in figure 2.

These components include:

- Supporting infrastructure (i.e. hardware, software, telecommunications, networks, etc.)
- e-business promotion (i.e. how business is conducted, any process that an organization conducts over computer-mediated networks),
- e-commerce innovation (i.e. transfer of goods, for example when a book is sold online).

As shown in figure 2, every digital economy is powered by skills embedded in STEM developmental culture. With STEM education, people with the high-end skills will be needed to invent and apply new technologies which are in high demand globally as depicted in figure 2. To deliver the needed change in Nigeria, the severe shortage of STEM skillset gaps must be filled up quickly in this knowledge-cloud era.

3.2 STEM versus Non STEM Employment Potentials

A sure way to raise the per capita earnings of the Nigerian economy is to increase the number of STEM graduates from both the secondary and tertiary levels. Ben [11] explained that STEM occupations offers higher pay than non-STEM employments. Globally, it has been shown that increasing the number of secondary school, graduate and postgraduate students majoring in STEM subjects is critical for national capacity building and its attendant economic prosperity. According to David et al [12], at different levels of educational attainment, STEM workers wage seems more attractive when compared with non-STEM workers.

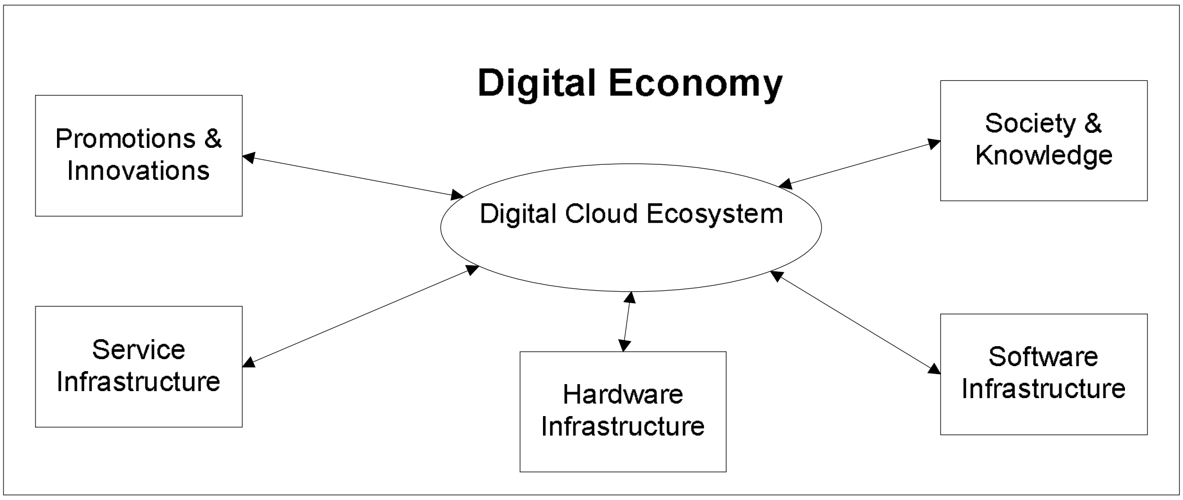

Figure 2: Subsystems of a Digital Economy

3.3 STEM Capacity Building versus Employment Security

Nigeria is full of untapped potentials with little STEM skillsets. Across the globe, STEM jobs account for a significant percentage of the employment window. These types of jobs are growing much faster than other job categories with greater security. This means the supply of STEM workers is unlikely to outstrip demand. Over the past decade, STEM jobs grew three times faster than non-STEM jobs particularly in Nigeria. Ross, et al [13] explained that a rich innovation pipeline plays a pivotal role in a nation's industrial development, commercialization, competitiveness, and ability to sustain long-term growth. Therefore, the STEM workforce is a powerful component of this innovation pipeline. Employment security is evidenced in STEM career fields as the workers contribute meaningfully to the economic development of any nation.

With advanced technologies like big data analytics, Internet of Things, augmented reality and other disruptive technologies, STEM workers will be in high demand in these areas. Hence, national capacity building in the knowledge economy depends on the number of STEM graduates that the secondary and tertiary institutions can produce yearly.

4.0 Modified STEM in Knowledge Era

Figure 3 shows a proposed Modified STEM for the digital economy. It is an extension of STEM with sustainable development as part of its core focus. It represents a holistic framework where the objective goal is to develop solutions that will be of benefit to the society and nature while remaining compliant to the digital economy. This implies that the students, teachers and stakeholders are integrally involved as it is a problem solution model.

With the proposed M-STEM framework, policy makers can engage employers in meeting the skills challenges facing high value-added sectors. This is because survival in a digital economy now demands higher-level cognitive skills for understanding, interpreting, analysing and communicating complex information.

If the projections that Africa's population is likely to double by 2050 come through, effectively harnessing available resources will be necessary to make the Continent more competitive while increasing people's living standards. As such, an improved STEM with sustainable development culture will suffice.

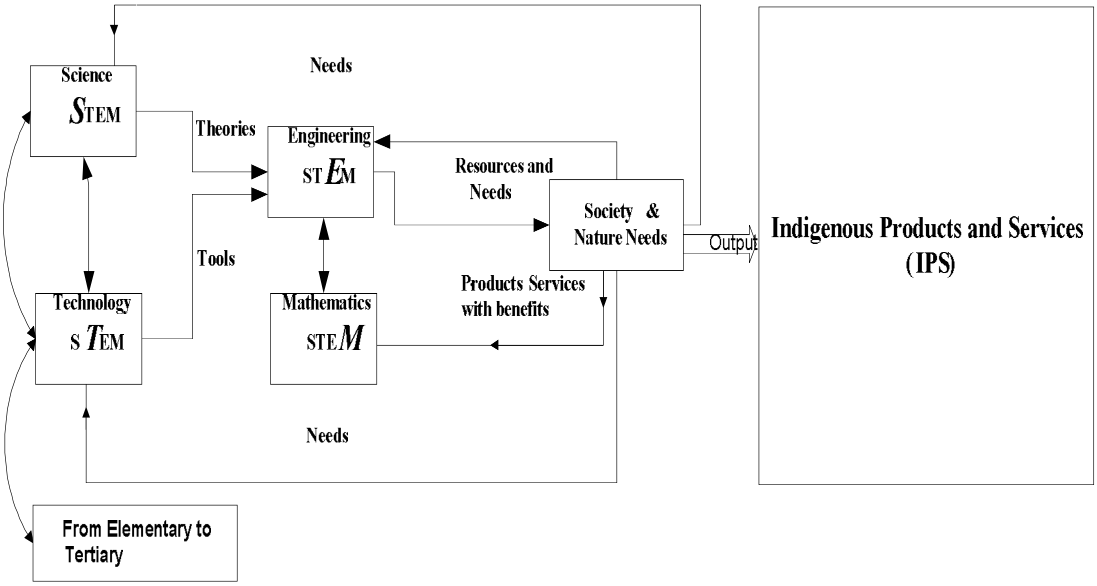

Figure 3: A Proposed Framework for M-STEM in a Digital Economy

To satisfy the requirements of proposed framework, there is need to consider the following:

i. Co-designing M-STEM materials, curriculum and approaches with experts in the industry, schools, universities/tertiary, and other knowledgeable stakeholders.
ii. Investigate promising and transformative ways of teaching and using new M-STEM technologies.
iii. Study the implementation of curricular innovations in STEM fields.
iv. Provide a scientifically grounded perspective on the challenges of improving policies and practices

Considering figure 3, the four identified cardinal goals of M-STEM educational framework is enumerated in Tables1 and 2. By keeping these objectives in mind, educators can develop a set of practices intended to meet these specific goals.

Table 1: Goals of M-STEM Education for Sustainable Development

Ensure a STEM-Capable Citizenry	This will build the Nigerian workforce that has the knowledge, conceptual understandings, and critical-thinking skills.
Build a STEM-Proficient workforce	This will adequately prepare a sufficient number of workers for job openings in STEM-related careers which are expected to increase in coming years.
Cultivate future STEM experts	By educating the best STEM experts in Nigeria. This will contribute to the economic growth, technological advancement as well as fostering a general understanding of the society. Also hunger, disease, and poverty will be reduced drastically.

Close the gender achievement and participation gap.	This is targeted at increasing women and minority participation in STEM fields in order to tap into Nigeria's full potential.

Table 2: M-STEM Educational Subjects for Sustainable Development

Science: (M-***S***TEM)	Biology, Chemistry, Physics, General Science (Food, Agriculture, Social, Environmental, etc.)
Technology: (M-S***T***EM)	Information Systems/Security Intelligence, Software Development/Web Programming, Cloud Computing /IoT Technologies
Engineering: (M-ST***E***M)	Chemical Engineering, Civil Engineering, Computer Engineering, Electrical/Electronic Engineering, Mechanical Engineering, Agricultural &Bio-resources Engineering
Mathematics: (M-**STE*M***)	Mathematics, Statistics, Modelling & Simulations

The other micro-components of the proposed framework include:

i. Integrated digital elementary school mathematics curriculum which is a multi-year study that examines whether and how an elementary digital mathematics curriculum can improve student learning
ii. Thinking outside the Box: This involves integrating dynamic mathematics to advance computational and critical thinking for students at all levels.
iii. Integration of computer science and mathematics concepts in a middle school courses.
iv. Practical vendor certification courses in M-STEM disciplines.

Considering figure 3, this paper opines that an early and repeated exposure to the detailed M-STEM subjects is essential for cultivating both future interest and aptitude in the subjects. Hence, the M-STEM education must begin in elementary school and continue throughout secondary school because this is when interest in science and math is typically developed. The advocated instructional techniques should include:

- Increased use of relevant, practical, application-based approaches
- Integration of content across disciplines from the early grades
- A focus on depth of learning and thinking as opposed to practice-memorization
- Use of alternative pedagogical techniques for effective communication of M-STEM concepts. Examples are traditional, teacher-led instruction, project-based learning, workplace/ lab-based learning, and use of technology-supported learning tools.

With strong academic preparation in elementary and secondary schools, M-STEM degree completion rates will be improved.

4.1 Advantages of Proposed M-STEM Education in Nigeria

There are numerous advantages of the proposed M-STEM framework considering the Nigerian context. The following are the merits of the proposed M-STEM.

i. Through M-STEM education as derived from Figure 3, students will learn to become problem solvers, innovators, creators, and collaborators and go on to fill the critical pipeline of engineers, scientists, and innovators so essential to the future of Nigeria nation.

ii. M-STEM education removes the traditional barriers erected between the four disciplines, by integrating them into one cohesive teaching and learning paradigm.

iii. M-STEM will inspire and prepare students to seize the opportunities of the global society through innovation, inquiry, collaboration, and creative problem solving.

iv. M-STEM careers will lower unemployment rates thereby granting greater job security in the knowledge economy.

v. M-STEM education is rigorously more practical than theoretical, but leverages underlying theories to evolve sustainable and immediate solutions to human problems.

vi. Finally, STEM education will boost the competitive edge and innovative capacity of the citizenry.

4.2 M-STEM Best Practices

A good STEM policy concept must satisfy key metrics in order to validate its success. To ensure an effective M-STEM educational initiative, the following best practices and elements must be followed to prepare students and teachers for the challenges and opportunities in the 21st century economy.

- Programme Implementation taking cognizance of continuous academic support structures for students e.g. mentoring, monitoring, activity societies, counselling, advising, scholarship programmes, teacher recruitment, professional development and assessment practices/evaluation.
- Programme Sustainability by considering:
  - i. Building and maintaining local capacity for continuous improvement to STEM structures.
  - ii. Iterative feedback and evaluation must be maintained while implementing changes to the system including instructional models and professional development for teachers.
  - iii. Engaging teachers in practicing concrete tasks related to teaching, assessment, and observation of learning with targeted results in mind.
  - iv. Including collaboration, sharing and exchange of ideas and practices.
  - v. Providing modelling, coaching, and problem-solving around specific areas of practice.
  - vi. Creating learning programmes that are job-embedded, and hands-on.
  - vii. Improvement of content knowledge and pedagogies of STEM subjects through in-service graduate programmes in universities and related tertiary institutions e.g. PostGraduate Diploma in Education (PGDE) programme for M-STEM teachers without teaching qualification, [14];
  - viii. Professional teacher-support STEM mentoring programmes should be encouraged at the secondary school level.

5.0 Open Challenges

To develop a workforce that will fit the digital economy, the gaps identified in the dysfunctional educational system must be re-engineered to solve the problems of weak performance of students in STEM subjects in external exams such as GCE, NECO and SSCE. Also, the harmonization of various stakeholders in the STEM paradigm will improve the success rate. Other issues such as stakeholders attitude towards causes of disruptions in educational institutions; inconsistencies in the educational reforms and policies as a result of policy deviations; lack of political will to implement policies on education vis-à-vis STEM education, poor attitude of supervisors towards monitoring of teaching, and learning as well as inadequate funding needs to be addressed.

6.0 Remediation and Discussions

To be successful in national capacity building in the digital era, efforts must be made to improve schools and raise student achievement include advancing students to understand M-STEM basic subjects on time. The following actions can be leveraged to address the challenges of STEM educational deficiencies:

i. Leverage and adopt rigorous mathematics and science standards with improved assessments. An M-STEM, Unified Standards Initiative (M-USI), led by Head Teachers, Principals, Vice Chancellors and other educational interest groups should be formed and charged with the mandate of implementing more rigorous internationally benchmarked mathematics standards. These efforts must be complimented by the various educational regulatory bodies like WAEC, NECO, NUC, NBTE, NABTEB, NTI etc.

ii. Recruitment of vendor industry certified experts as well as retraining of staffs that are qualified to become classroom teachers. In this regard, corporate organizations, in partnership with the Federal government can mobilize financial incentives, support systems, professional development, and improved institutional conditions to recruit, retain and reward high-performing math and science teachers.

iii. Provision of more rigorous preparatory curriculum for STEM students. This can be done through modified school and instructional designs (i.e. STEM-specialty courseware), early college programmes, linked learning, and online courses providing students with more focused and rigorous STEM curricula with real-world applications.

iv. Introduction and usage of informal learning to expand mathematical and sciences beyond the classroom experience. In this regard, many public and private institutions, such as museums, science centres, and internship programmes, could provide valuable out-of-class experiences that demonstrate how mathematics and sciences connect to everyday life and careers, and allow students and teachers to expand their skills. These programmes can be proved to have a positive effect on STEM interest and achievement.

v. Enhancement of the quality of STEM teachers. There should be policy or regulations on consistently improving teacher preparation programs, providing support systems and professional development, while generating more qualified mathematics and science teachers as well.

vi. There should be established goals for postsecondary institutions to meet STEM job needs in this knowledge driven era.

vii. There must be a high supply of STEM teachers both at the basic and senior secondary school levels. The use of learner-centred methodology should be recommended and practiced while appraisal of schools should be focused more on process oriented activities than learning outcomes.

viii. After-school programmes and graduate internships in STEM disciplines.

ix. Introduction of M-STEM contests for rewarding creativity and problem solving.

For a sustainable national capacity building in a digital economy, the above recommendations will definitely begin to increase the number of students and professionals engaged in M-STEM fields and occupations.

7.0 Conclusions

This paper has tried to identify the gaps in the existing STEM educational framework in Nigeria while proposing an emphasis based M-STEM framework which inherits from the traditional STEM initiative. As a tool, it places an emphasis to learning outcomes using the classical theories in the generic STEM. The advantages of the proposed framework in a digital economy were outlined. By increasing the number of students that are knowledgeable in M-STEM, and growing the number of graduates pursuing M-STEM careers or advanced studies, the economic prosperity of Nigeria will be guaranteed. It is opined that the knowledge economy seriously needs experts with rich supply of M-STEM-skillsets. To ensure that Nigeria does not get lost in the path of national capacity building, educational policy makers and critical stakeholders at all levels must support the new emphasis on M-STEM education across all tiers, i.e. from primary to tertiary.

Furthermore, the implementation of M-STEM education in schools will reasonably prepare the future workforce with strong scientific and mathematical backgrounds which will enhance skills development across M-STEM disciplines. Finally, it is suicidal to create a society that depends on science and technology in which no one knows about science and technology. Consequently, with continuous supports, monitoring and feedback, M-STEM graduates can turn scientific breakthroughs into useful products and services.

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