REFORMS IN SCIENCE, TECHNOLOGY, ENGINEERING AND MATHEMATICS (STEM) EDUCATION

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1.0. INTRODUCTION

Science, Technology, Engineering and Mathematics (STEM) education often has been called a meta-discipline, the ‘creation of a discipline based on the integration of other disciplinary knowledge into a new ‘whole’. This interdisciplinary bridging among discrete disciplines is now treated as an entity, known as STEM (Morrison, 2006).’ STEM education offers students one of the best opportunities to make sense of the world holistically, rather than in bits and pieces.

STEM education removes the traditional barriers erected between the four disciplines, by integrating them into one cohesive teaching and learning paradigm. This explains why Morrison and others have referred to STEM as being an interdisciplinary approach. It is also explicable that Tsupros (2009) refers to STEM education as an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons with a view to ensuring that students apply science, technology, engineering, and mathematics in contexts that make connections among school, community, work and the global enterprise maximally harnessed to enable the development of STEM literacy and with it the ability to compete in the new economy. It is thus imperative that Nigeria imbibes the concept of STEM education particularly in this era of globalization and when most nations desire to achieve the targets of EFA and MDGs. This conference theme-Reform in STEM education is very apt at this point in time when our nation seeks to become one of the top 20 economies in the world by the year 2020 (vision 20:2020).

In order to have a thorough grasp of this keynote address, we will be guided by the following outlines:

- ❖ Background to STEM education in Nigeria.
- ❖ STEM education outside Nigeria
- ❖ globalization and STEM education.
- ❖ Nigerian STEM education reforms.

- evaluation of the reforms in STEM education.
- way forward in STEM education.

2.0 Background to STEM Education in Nigeria

Prior to 1859, no science was taught in any part of Nigeria. The first mention and teaching of science was in 1859, when the first Secondary School (CMS Grammar School, Lagos) was established. Then, arithmetic, algebra, geometry and physiology were introduced into the school curriculum (Ivowi, 1999). Between 1859 and 1929, several secondary and teacher training institutions were founded with other science subjects such as astronomy, chemistry, geology and botany introduced into the curriculum. However, available evidence (e.g Ivowi, 1999) indicate that even from the onset, science teaching and learning suffered some setbacks leading to poor performance at end of school programme.

In 1920, the Phelps-Stokes Education Commission visited West Africa and noted that the state of science education was deficient. Consequently, a strong recommendation was made to ensure that science subjects were included in the secondary school curriculum in Nigeria. However, at that time, very few competent science teachers were available in few schools and the provision for science as well as method of teaching science was very unsatisfactory (Ivowi 1999).

Before 1960, most secondary schools in Nigeria emphasized classics and art subjects with little emphasis on sciences. Science teaching and learning in schools was a mere privilege. The attainment of political independence in 1960 marked the start of a new era in a number of activities in Nigeria. The first organized curriculum development effort took place at the Comprehensive High School, Ayetoro in 1963. The impetus for science curriculum development efforts may be ascribed to the formation of Science Curriculum Development Committees in 1968 under a cooperative agreement between the Comparative Education Study and Adaptation Centre (CESAC) and the Science Teachers Association of Nigeria (STAN). The membership of these committees was drawn from both bodies, the Universities and Ministries of Education.

The Committees produced the first set of indigenous syllabuses in Integrated Science, Biology, Chemistry and Physics. Following the production of these syllabuses, both CESAC and STAN developed science projects which proposed radical changes in content, context and sequence of teaching science in secondary schools. These included STAN Nigeria Integrated Science project

(NISP), CESAC Basic Science for Nigeria Secondary Schools (BSNSS) and CESAC Nigeria Secondary Schools Science project (NSSSP) for Biology, Chemistry and Physics. In September 1969, there was a National Curriculum Conference in Lagos which drew a lot of participants from diverse backgrounds who were eager to see Nigeria chart a new course in its educational system.

At the primary school level, there were two pioneering projects developed between 1970 and 1977 by the Bendel State Ministry of Education and the Institute of Education Ahmadu Bello University, Zaria. The projects had the support of UNESCO/UNICEF. The apparent success of these projects led to the production of a number of primary schools courses by the State Ministries of Education, the Nigeria Educational Research and Development Council (NERDC) and individuals. A national core curriculum in primary science was also developed with clearly stated objectives and activities (FME 1980).

Another giant stride in science development in sub-Saharan Africa was the African Primary Science Programme (APSP). The programme which brought together educators and scientists from eleven English speaking African countries was the first of its kind. The programme which was a research and development project was sponsored by the Educational Services Incorporated (ESI), which later became Education Development Centre (EDC), in Massachusetts, U.S.A in the 1960's (Yoloye, 1978).

The broad goal of the APSP with respect to the African child was to ensure the development of the following characteristics in children:

a. first hand familiarity with a variety of biological, physical and man-made phenomena in the world around them,
b. interest in further exploration of the world around them on their own initiative,
c. ability to find out for themselves, i.e. to see problems and to be able to set about resolving them for themselves.

The program initially embarked on the production of science teaching materials which were mainly teachers' guide and to a lesser extent, pupils' books and a science library series for background reading. At a later stage, the program embarked on formative evaluation of science teaching activities to ensure functional teaching of science at the primary school level.

2.1 STEM EDUCATION OUTSIDE NIGERIA

2.1.1 STEM EDUCATION IN U.SA.

In the 1950s and 1960s, the sputnik inspired a generation of Americans to pursue education and careers in science and technology. Consequently, for over half a century, science based innovation has powered America's economy, thereby, creating good jobs, high standard of living, and political leadership. For several decades, educational reform in Science, Technology, Engineering and Mathematics (STEM) has involved many people and organizations. To produce a STEM literate society, many STEM organizations have produced a variety of publications aimed at improving STEM education in the United States of America. These publications have influenced STEM education reforms and innovations at various levels in USA and in several nations of the world today.

Some of the major reforms in STEM education in the U.S include science for all Americans, the young Naturalist Awards, Systemic Reform, National Science Education Standards Project, Scope Sequence and Coordination, Architectural Construction and Engineering (ACE) Mentor Programme, Race To The Top (RTTT) and Educate to Innovate. Education reform efforts in the U.S. have steadily widened to include improvements in the quality, access and real-world relevance of science and mathematics at every educational level. The Americans believed that a STEM-educated workforce is vital to the security and prosperity of the U.S.A., as industry and government increasingly demand highly trained STEM professionals to compete in the global market. For the Americans, the purpose of driving STEM education is not principally to create economic opportunities for individuals but to provide the fuel needed to power a science and technology driven economy as well as stay one step ahead of national security threats.

2.1.2 STEM EDUCATION IN CHINA

The theoretical foundation for the current education system in China can be traced to the "Decision on the Reform of Educational Structure", a decree issued in 1985 by the central committee of the Chinese Communist Party which was formalized a year later by the National People's Congress with the ratification of the "Compulsory Education Law" (U.S. Library of Congress, 2010). This new law served as the basis for reform at all levels of education in China.

The government sees the leadership commitment to basic education as a legal and a moral imperative. In line with the Chinese adage that it takes a decade to grow a tree, but a century to educate people, the core of these reforms was rooted in the belief that in order to prepare the country for the 21st century, it was necessary to develop all sectors of education, the most vital of which included elementary and secondary education.

In pursuit of her objectives, the Chinese government granted administrative power to municipal and provincial governments to organize and regulate public education on the basis of local needs and conditions. This was with a view to universalizing basic education for the rural poor, including ethnic minorities, The result was an increasingly diversified curriculum that reflects the integration of local and national agenda, whereby courses are both pre-determined by the state and developed by provincial level education departments to incorporate the needs and priorities of individual schools and districts.

Recently, the Chinese president, Ma Ying-Jeou stressed the importance of educational reform as the foundation of the nation's next 100 years. The president believed that education is the cornerstone for nation building and educational reform a panacea to national, economic and social woes. This reform was focused mainly on innovation in STEM education.

In order to actualize this dream, the Chinese President has proposed that by 2014, high and vocational high schools will be tuition-free and in most cases will require no entrance examination.

Several reports have revealed that China is producing a high number of STEM college graduates who will power their technology driven economy. Chinese officials recognized that STEM is more important than other subjects because the overall societal contribution from a STEM graduate exceeds that of a social scientist or humanities major (Atkinsons and Mayo, 2010). It is in this light that China is seen as a threat to the U.S. innovation and economy.

2.1.3 STEM EDUCATION IN FINLAND

This paper will take a look at a small country that has made a remarkable success economically and technologically and thus became the envy of the world super-powers. This country is Finland.

Finish students outperformed their peers from 43 other nations – including the United States, Germany and Japan in Mathematics, Science and reading skills in the Programme for International Students Assessment (PISA OECD, 2000). Finland was also ranked top in the global economic competitiveness. This performance, according to the World Bank report (2006), published in Policy Development and Reform Principles of Basic and Secondary Education in Finland since 1968, did not come by chance but sprang directly from educational policies set in motion 40 years ago (Maes, 2011).

Some distinctive features of this policy reform include:

- Education is free at all levels.

- When Finish kids turn 7 years old, they go into nine years compulsory primary schools. All kids start at the same level, no matter what socio-economic background they have.

- All teachers are prepared in academic universities. Teachers are highly respected and appreciated in Finland, partly because every teacher needs a master's degree to qualify for a permanent job.

- The government, the trade unions and employers' organization form a tripartite in Finland, adopt a common front to closely monitor and coordinate reform activities.

- Since the 1960s political authorities have always seen education as the key to survive and thrive in an increasingly competitive world. To be competitive, the government concluded that Finland has to substantially boost investments in education research to foster innovation and cutting edge development.

- There are no mandatory tests or exams. Teachers make their own tests, not quoting numeric grades, but using descriptive feedback, not comparing students with one another.

- Schools have full autonomy in developing the daily delivery of education services. Schools plan their own curricula to reflect local concerns.

- In high education, the Polytechnic system was considered top priority for regional development and was given more attention (in 1990s) compared with University education.

- The teacher unions and educators are considered experts and are engaged in designing education framework and policy formulations.

- School principals, management and local political authorities as well as teachers are carefully selected for their understanding, experience and solid proven management skills.

Apart from the fact that Finland has beautiful school buildings, well trained teachers, state of the art technology and fancy text books, they equally got it right at the policy level which has earned remarkable success and achievement in STEM education.

Today, Finland's comprehensive system is noted as one of the most effective in the world and is an example of a nation that has been able to transform her traditional economy into modern technology driven economy within a relatively short time using STEM education as a spring board.

2.1.4 LESSONS FROM REFORMS FROM USA, CHINA AND FINLAND

An examination of the various reforms in STEM education in the three countries under study indicates that countries with functional STEM education:

- attach high priority to it backed with sound policy guide lines and effective implementation strategies.

- lay more emphasis on teacher quality, through certification, accreditation, training and retraining in STEM subjects.

- devote a big chunk of their budget on education in STEM subjects at all levels of education.

- make education especially at the basic level tuition free.

- consider teachers as experts and major stakeholders in education decision making and policy formulation.

3. GLOBALIZATION AND STEM EDUCATION

Jacques Hally (1998) defined globalization as a combination of free trade in goods and services combined with free capital movements. It means that a nation's investment, production, and innovation are not limited by national borders. This globalisation became possible only recently because of the technological infrastructure provided by telecommunications, information systems, microelectronics machinery and computer-based transportation. The idea of globalization is relatively new and most of the technologies that have fuelled it have been around for less than three decades.

Two main bases of globalization are information and innovation, which are in turn highly knowledge intensive (Carnoy, 1999). Inter nationalized and fast growing information industries produce knowledge goods and services. Today's massive movements of capital depend on information, communication, and knowledge in global markets. Knowledge is highly transmissible, hence it lends itself easily to globalization. In this regard, since knowledge is fundamental to globalization, then globalization should also have a profound impact on the transmission of knowledge. Some, however, have argued that this has not occurred, casting doubt on the capacity of globalization to permeate local culture-influenced knowledge production and transmission. They opined that education appears to have changed a little in most countries at the classroom level while teaching methods and national curricula remain largely intact and globalization seems to have little or no effect on educational delivery.

However, Carnoy holds a strong view that globalization is having a profound effect on education at many different levels and will have even greater effect on it in the nearest future as nations, regions and localities fully comprehend the fundamental role of educational institutions. This role is not limited to transmitting skills needed in the global economy but also in reintegrating individuals into new communities built around information and knowledge.

The principal role of education has been the development of a whole individual. The minimum level of education that was necessary to achieve this goal in the agrarian society was basic or primary and in the industrial age, secondary. In the present borderless information dominated society, education needs to be able to respond to additional demands of a rapidly globalizing world by raising awareness of environment, peace, cultural and social diversity, increased competitiveness and the concept of global village. Such education is to a knowledge or international society what secondary education was to industrial economy.

Education prepares the individual to connect, and live in harmony with the environment around him. Globalization has changed the size, nature and quality of that environment. The challenge of STEM education therefore is to reform, create and develop a system that prepares the individual to work in a borderless economy and live in a global society. In other words, STEM education needs to produce global citizens.

4.0 NIGERIAN STEM EDUCATION REFORMS

The following are key issues on reforms in STEM education in Nigeria.

4.1 Government Policies with respect to Stem.

In the National Policy on Education (2004), the Federal Government of Nigeria (FGN) came up with some policies that were meant to develop and promote the teaching and learning of STEM at various levels.

- Government prescribes that the Curriculum of Primary Education shall include among others: Mathematics, Science, Agricultural Science, Physical and Health Education etc. Specialist teachers shall be employed to teach subjects such as Mathematics, Science, Physical Education, Home Economics, etc. The policy maintained that teaching at the primary school shall be by practical, exploratory and experimental methods.

- At the secondary school level, the government policy is that secondary education shall be for six years duration at two stages: basic and post-basic secondary schools. At the basic level (former JSS), the students are expected to be taught among others: Mathematics, Basic Science, Basic Technology, Computer Education, Agricultural Science, etc. Similarly at the post-basic level, students are expected to study Mathematics, Biology, Chemistry, Physics, Agricultural Science, Applied Electricity, Auto Mechanics, Building Construction, Electronics, Computer Education, Metal Work, Wood Work, Technical Drawing, etc.

- At the tertiary education level, the policy specified the following:

    i. a greater proportion of expenditure on university education shall be devoted to science and technology.

    ii. not less than 60% of places shall be allocated to science and science-oriented courses in the conventional universities and not less than 80% in the universities of technology.

    iii. admission into the technology and business courses shall be weighed in the ratio of 70:30.

    iv. establishment of STEM-based institutions such as the polytechnic, monotechnic and trade centres.

4.2 Policy Implementation with respect to Stem

The Federal Government of Nigeria did not lose sight of providing the various modalities or strategies for implementing the policies at the various levels of education with respect to STEM.

Specifically at the primary level, the government indicated that **efforts will be made to** provide the following educational services: school library, basic health scheme, counseling, educational resource centres and provision of specialist teachers in schools. It also maintained that teaching shall be practical, exploratory and experimental in nature with the medium of instruction being in English Language and the language of the immediate environment.

At the secondary level, government promised that education shall be **tuition free, universal and compulsory**. Basic subjects as mentioned earlier shall be taught to enable them acquire further knowledge and skills. Youth clubs (e.g. JETS club), organizations and school societies shall be encouraged as important instruments for character training and mental development.

4.3 Step-B Project

STEP-B Project is an acronym for Science and Technology Education Post-Basic Project and is purely a Nigerian project in Science and Technology at the post-Basic level. It is a World Bank assisted Project in collaboration with the

Federal Ministry of Education (Abuja) with the following specific objectives that relate to education and research in Nigeria:

- for Nigerian education and research institutions and their partners to produce more and better qualified science and technology graduates at the post-basic level; and
- for the same institutions to produce higher quality and more relevant research.

As a reform strategy, the STEP-B project was expected to deliver the following benefits to the educational system :

- increase in the number of students trained in science and technology (S&T) related areas.
- improvements in quality (e.g. more publication, more collaborations between researchers in the public and private sectors, and between institutions in education and research, and between Nigerian institutions and their partners internationally.
- improvements in teaching and learning of S&T (e.g. opportunities for better teacher training or improvements to technical and vocational education and training, or perhaps better use of computers and the internet as tools for teaching and learning).
- improved relevance of S&T education and relevance to the needs of Nigeria.

The institutions that were eligible to participate in the STEP-B Project are:

- Federal Ministry of Education (FME).
- Federal Ministry of Science and Technology (FMST)
- Universities, Polytechnics, Colleges of Education.
- Research Institutes under FMST.
- Federal Government Colleges as well as Federal Science and Technical Colleges.

The Federal Ministry of Education (FME) is the main STEP-B Project implementation agency in collaboration with the Federal Ministry of Science and Technology (FMST). However, FME has the overall responsibility for project co-ordination and implementation. At present the first phase of STEP-B Project in Nigeria has kick started and about to be completed.

4.4 Technology Transfer in Nigeria

One of the ways of reforming STEM education in Nigeria as suggested by Okongwu (2008) is through Technology Transfer. Technology transfer is the tendency of technology acquisition from one nation to another simply for the purpose of national development. Transfer of technology is a very complex process involving a myriad of cultural, socio-economic, environmental, intellectual, infrastructural, political and other related factors.

In Nigeria, efforts towards technology transfer has suffered some constraints due to the widening innovation gap between Nigeria and the developed countries as well as the nation's poor culture of innovation, the rapid changes in innovation and the shortening life span of innovation cycles. A critical review of 1956 – 1981 era shows that there was a massive importation of capital goods and establishment of very critical industries. In this regard, even though technology inflow was appreciable, the internalization of technology was not.

The state of Nigeria's technological development so far seems to look like that of the movement of an individual staggering about in the manner of a Brownian motion or more correctly a sleepwalker on a platform that is moving rapidly in the opposite direction, such that the net motion of the sleepwalker is really backwards. One of the key issues that has not been given adequate attention as far as technology transfer in Nigeria is concerned is how to construct a RECEPTOR which captures the transferred technology and ensures that it is fully internalized to enable it blossom and grow to create similar new technologies on its own within a given time frame shun of external support. It is only on this premise that we can confidently say that technology is said to be transferred.

The importance of a deliberate RECEPTOR programme cannot be over-emphasized because without it, technology transfer will be a chance thing. Data shows that Nigerian's National Research and Development (R&D) intensity under the Science and Technology Ministry is about 0.06% compared to South Africa (0.7.%), China (1.40%) and India (1.2%). In this case, there is the need to beef up the R&D expenditure to yield a national R&D intensity of at least 1.0% within the next six years i.e. by 2014 and to exceed 2% by 2018 (Okongwu, 2008).

Based on the above statistics, it appears that there is technology transfer problem in Nigeria. This demands that transfer of technology must effectively start by improving the quality of teaching and learning of STEM subjects at all levels of the educational system. It requires a culture that encourages spirit of enquiry, freedom of thought, sound academic/work ethics, discipline, high regard for truth and integrity, reward for hardwork/accomplishment, public spiritedness, justice and the like which will generate a technology-promoting culture. In a society where the above exist, innovation will sprout and abound, technology will develop and blossom, entrepreneurialism will flourish and thus rapid development.

For a vibrant technology transfer through STEM education in Nigeria, we must ensure that the following are put in place:

- upgrading technological governance;
- enthroning a culture of innovation;
- strengthening intellectual property system;
- developing human capital with strong entrepreneurial base;
- establishing strong technology support structures;
- creating technology transfer receptor programs;
- increasing R&D intensity; and,
- infusing a technological culture and a new mindset.

4.5 Indigenization of Technology

In the earlier part of this paper, we looked at the concept and importance of technology transfer as a reform tool that will help in improving the quality of a nation's technological development. This involves importing knowledge and technical know-how from developed nations to a developing nation such as Nigeria. In doing this, less developed countries will acquire modern techniques that would be useful in their industrial establishments as well as in research, training and schooling centers.

With the emergence of a new world order called globalization, every nation of the world is aspiring to become one of the twenty economies. This has therefore necessitated the adoption of reforms in the educational and industrial sector through revitalizing STEM education. The new reform designed by some nations of the world in meeting up with this objective is that of indigenization of technology.

Indigenization of technology is the adaptation of borrowed technological know-how to suit your immediate local needs.

Since education makes an individual person to realize his/her full potentials to contribute to the well being of the community/society and lead a personally fulfilling life, there is the need to advocate for a functional traditional education system which will transmit the local culture, ideas, knowledge and technology into the lives of the educated populace. A very good case in point is that of the Singaporean government which enacted a curriculum reform policy in addition to the marketing of education policy. This was designed in order to make sure that the curriculum in the school (STEM in particular) is so structured to provide local content both in materials and methodology.

In Singapore, the curriculum reform under the indigenization of technology framework led to three major initiatives:

- ❖ the thinking school, Learning Nation Initiative.
- ❖ the master plan for Information Technology in Education Initiative.
- ❖ revisions to the University Admission Criteria.

In order to achieve these set targets, the following strategies were adopted by the Singaporean government:

- ✓ the explicit teaching of critical and creative thinking skills.
- ✓ the reduction of subject content.
- ✓ the revision of assessment modes.
- ✓ a greater emphasis on process rather than outcomes when appraising schools.

For Nigeria to attain a successful indigenization of technology, we must have to concentrate on the provision of basic education for all. 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.

5.0 EVALUATION OF THE REFORMS IN STEM EDUCATION

Okpala. et.al (1993) defined evaluation as a process of gathering valid information on attainment of educational objectives, analyzing and fashioning the information to aid judgment on the effectiveness of teaching or an educational programme. In the light of this definition, every reform on STEM education should be regarded as a programme and as such there is the need to ascertain the effectiveness or efficacy of the reform in meeting up the objectives for which it was designed to achieve. The kind of evaluation required in this case should be formative because the results from it will be used to provide feedback to the relevant stakeholders such as students, teachers, parents, administrators, the developers of reform and the policy makers.

The question one may ask is: what are the critical issues in STEM education in Nigeria? An attempt to answer this will lead us to critically examine the level of performance of students on STEM subjects in public examination in Nigeria using tables I and 2.

5.1 Level of Students' Performance in NECO SSCE at the National Level

The index used for the students' performance at the national level is the number of candidates who had 5 credits and above including English Language and Mathematics in the 2009-2010 NECO June/July SSCE. (See appendix I). Highlights of the results in the two (2) years are:

- 126,543(10.67%) and 105,989 (9.36%) candidates respectively had 5 credits and above including English Language and Mathematics.

- The performance was not encouraging for the educational system

5.2 Level of Students' Performance in SSCE STEM Subjects

Table 2 (see appendix II) shows the students' performance in eleven (11) subject areas, namely Mathematics, Further Mathematics, English Language, Literature-in-English, Biology, Physics, Chemistry, Applied Electricity, Technical

Drawing, Auto Mechanics and Woodwork. In a nutshell, the performance of candidates in STEM subjects at the SSCE over the years under review is generally poor as our students can be adjudged to be intellectually weak especially in STEM subjects. This demands a serious evaluation of STEM education in Nigeria. It is therefore pertinent to identify some critical issues in STEM education that need to be looked into so as to improve upon the existing order.

5.3 Critical Areas of Concern in Stem Education

As matters arising from the candidates' poor performance on STEM subjects in NECO SSCE, one may be worried to ask the following fundamental questions:

- To what extent do students learn STEM subjects, i.e. level of seriousness? (How do they apply themselves to the learning of STEM subjects)
- What and how do teachers teach (are teachers actually teaching STEM subjects very well)?
- How conducive is the learning environment in schools?
- Are the instructional materials and other learning aids available and adequate?
- What are the levels of interactions between:
  -students and teachers,
  -students and students
  -students and learning materials and
  -teachers and instructional materials?
- What efforts had parents, PTA, old students' Associations and Government made towards improvement of teaching and learning of STEM Education?

An attempt to answer these questions may require a critical appraisal of the problems through 'action research studies' with a view to providing empirical information that will inform policies and reforms especially in the area of STEM education. However, one is more inclined to share the view that the problem of students' underachievement in STEM subjects had been the concern of educators in the past four decades or more and so many empirical works on the problem had been documented in universities and public libraries in Nigeria and abroad. What the Nigerian educational setting actually needs is the professional and political will to implement the recommendations of these research reports on STEM. It is therefore important that this paper draws the attention of relevant stakeholders in Nigeria to the view that documented empirical studies reveal that students' poor performance in STEM subjects is associated with factors that could be grouped as follows:

5.3.1 ***Student Factors***

- lack of interest in their studies
- Poor study habits
- lack of knowledge of the relevance of the examination syllabus.
- over indulgence on programmes associated with new technologies e.g. computer games, English and European League matches, African magic etc.
- Poor interaction of students with STEM learning material.
- High cost of STEM books and other learning materials used by the students.
- Perceived difficulties of STEM subjects.

5.3.2 ***Teacher Factors***

- Poor quality teachers that are not prepared to take the teaching job very seriously.
- Insufficient quantity of trained STEM teachers.
- Preponderance of teachers that are conservative and unwillingness to accept changes and innovations in line with technological development.
- Non-completion of syllabus prescribed for different public examinations.
- lack of knowledge of the relevance of public examination syllabus.
- inability to teach abstract STEM concepts thereby making teaching and learning very difficult.

- Poor remunerations and incentive for teachers.

- Lack of capacity building for STEM teachers through in-service programme, workshops and conferences.

5.3.3 *School Factors*

- Learning environment devoid of appropriate physical facilities and lack of instructional and curricula materials.

- Great decay in quality of laboratories, workshops, libraries and absence of materials and equipment expected therein.

- Over population in the schools not commensurate with the number of teachers leading to high student-teacher ratio.

- Poor level of interaction between students and learning materials, between teachers and students and between teachers and teaching materials in the schools.

- Insufficient time for learning of tasks in the school.
- Dearth of guidance counselors in schools vis-a-vis STEM education in schools.
- Over emphasis of theory at the detriment of practicals in STEM subjects.

5.3.4 *Government Factors*

- Stakeholders' attitude towards causes of disruptions in educational institutions.

- Inconsistencies in the educational reforms and policies as a result of policy somersaults.

- Lack of political will to implement policies on education vis-à-vis STEM education

- Poor attitude of school inspectors towards monitoring and supervising of teaching and learning.

- Inadequate funding.

5.3.5 *Parents and other Stakeholders' Factors*

- Parents' lack of interest in what is happening in schools and their children/wards' academic pursuit.
- Stakeholders' poor attitude towards investing (NOT spending on) in education.
- Lack of home supports (e.g. provision of conducive learning environment in homes).
- High level of poverty in the entire society.

5.3.6 *Gender Imbalance in STEM Education*

Another critical area of concern is gender imbalance in STEM education. The concept of 'gender' is fast becoming a global issue especially in the educational sector. In recent times, issues on gender and development have been in the favour of women. The United Nations has been on the forefront in raising the status of women. It declared 1975 as International Women's Year and year 1975 to 1985 as the UN Decade for women. Thus in the last three decades special attention has been focused on women and their advancement in every sphere of life.

Gender stereotyping has permeated the school system both directly and indirectly in subtle ways. For instance, subjects like Physics, Chemistry, Mathematics, Technical Drawing and Applied Electricity, etc have been described as masculine subjects while subjects like Home Economics, Literature in English, Secretarial Studies, Biology, Home Management, etc were regarded as feminine. Female students are even reminded by their male teachers and in some cases, guidance counselors of the difficulties associated with subjects regarded as masculine.

Okeke (2001) argued that the percentage enrolment of female students and their pass rate at credit level and above were found higher in Health Science, Clothing and Textiles, Foods and Nutrition and Home Management than in Mathematics, Physics, Chemistry, Biology, Agric Science, Electronics, Auto Mechanic, Building Construction etc. Similarly, the enrolment and performance of female candidates at credit and above level were very poor in Technology subjects like Technical Drawing, Building Construction, Wood Work, Metal Work, Applied Electricity, Electronics and Auto Mechanics. In Basic Sciences, the enrolment of females is below 50% in all subjects with Further Mathematics being the worst. Okeke also pointed out that females were almost absent in most technical courses at the tertiary level of Nigerian education.

The extent to which gender equity has been attained with respect to participation and performance in STEM subjects has not been in favour of the females. A gender analysis of biographical data in Nigeria and in many other countries indicates that the female gender is grossly underrepresented in Scientific and Technological fields. Perhaps, we can further illustrate this imbalance by taking a census of the number of female scientists, science educators, mathematicians and technicians at this very STAN Conference. The case is the same in COREN (Council of Registered Engineers of Nigeria) and similar science based professional associations.

6.0 THE WAY FORWARD IN STEM EDUCATION

6.1 Targeted Support for Teachers, Students and Schools

6.1.1 *Teachers*

Teachers have crucial roles to play in ensuring the successful implementation of reforms in STEM education. In view of this, it is imperative that teachers should have a thorough mastery of both the theoretical and practical applications of STEM. To achieve this, it is necessary that:

- teacher training institutions be made to emphasize adequate knowledge of content acquisition and current pedagogical and entrepreneurial skills;

- teachers be encouraged to undergo regular in-service training, participate in workshops and conferences to strengthen their capacity as well as help to keep them abreast of current trends in STEM.

- professionals in STEM who are Nigerians in Diaspora be encouraged to return to the country and contribute to the advancement of STEM education.

- science teachers allowance be paid to STEM teachers to serve as incentive.

6.1.2 *Schools*

- Massive infrastructural development and provision of STEM instructional and curricular materials in all the schools should be given priority by the various tiers of government.

- Increase in government funding of education to enhance the quality of teaching/learning environment.

- More functional public and school libraries should be established in order to meet with the demands of studying STEM subjects.

6.1.3 *Students*

- STEM education should expose students to practicals to enable them acquire scientific skills, attitude and competencies.

- Improving the disposition of students in terms of attitude, study habits and motivation to study STEM subjects through the awards of scholarships, grants and prizes.

- Membership of Reading and Science clubs (e.g. JETS clubs) should be encouraged in schools.

6.2 Fostering Innovations

Fundamental to the growth of STEM education is innovation. This will not be realized until the goals of STEM education are better delineated and the meta-discipline of STEM education better defined; innovative STEM education programmes and curricula are developed and teachers are professionally educated to deliver STEM programmes and curriculum.

The following elements should be integral parts of the design of any STEM curriculum for the purpose of innovation:

- be *trans-disciplinary* in its overall approach;

- be *driven by standards* that complement the trans-disciplinary philosophy;
- use the backward mapping techniques advocated *Understanding by Design;*
- use both *problem-based and performance-based* teaching and learning approaches;
- be *digital in format and coupled with digital teaching technologies* such as whiteboards, tablets, student response systems, etc. and

6.3 Enhancing Partnerships

There have been calls for government to increase funding of education at all levels in order to advance the quality of teaching and learning. However, experience has shown that government CANNOT do it all alone hence the Public-Private-Partnership (PPP) approach to funding of education is advocated. Such funds should be geared towards:

- provision of infrastructure and adequate teaching-learning materials for laboratories and workshops at all levels.
- sponsorship of programmes like science fairs/projects, science and Mathematics Olympiad etc;
- retraining of qualified STEM teachers;
- awarding scholarships to deserving teacher trainees in STEM subjects.

Programmes such as the Nigeria-UNESCO special Science Technology and Engineering (STE) Project and STEP-B Project should be extended to all post-basic institutions in the country as a step towards the realization of the objectives of STEM education.

In order to achieve the Public-Private-Partnership funding, government must ensure that incentives such as tax rebate, are given to the business sector especially those who will be called upon for the partnership.

6.4 Improving Assessment

Assessment is an integral part of a sound educational process. Any strategic reform in STEM education must ensure a paradigm shift in assessment approach. The emphasis must shift from assessment of learning (summative evaluation) to assessment for learning (formative evaluation). Assessment should drive the ideals of science, by inculcating in the learners scientific attitudes, systematic enquiry and problem solving skills. Such assessment must be frequent and continuous. The aim is not to generate data for categorizing learners but rather to evaluate students' strengths and weaknesses, using descriptive feedback and remedial lessons in order to improve students' skills and knowledge acquisition.

Moreover, assessment programmes such as Monitoring of Learning Achievement (MLA) and National Assessment of Education Progress (NAEP) should be used to drive the study and improvement in STEM education. Such studies usually provide unbiased report of the state of education and data for description of performance level, as well as basis for policy formulation and implementation.

6.5 Strengthening Preparation Programmes for STEM Teachers

To ensure that more potential teachers, including STEM teachers have access to high quality training and retraining programmes, the following suggestions should be implemented:

- budgetary allocation to the education sector should be substantially increased.

- the subject content at both the colleges of education and the universities should be broadened so that teachers have a full grasp of the subject matter.

- all efforts should be made to attract and sustain brilliant and gifted individuals into the teaching profession particularly in the area of STEM.

- the entry- and exit performance criteria associated with teacher training institutions should be such that guarantee quality teaching work force that is needed to drive STEM programmes.

6.6 Relevant Professional Development and Collaboration Time

STEM education in Nigeria may not move forward to greater heights if we neglect some relevant professional development practices for teachers, students and schools. The following must be done in this regard:

- improvement of content knowledge and pedagogies of STEM subjects through in-service graduate programmes in universities and related tertiary institutions e.g. Post-Graduate Diploma in Education (PGDE) programme for STEM teachers without teaching qualification;

- Federal, State and Local Governments should provide more opportunities for teachers and students collaboration (e.g. exchange programmes). Such teacher collaboration will improve professional practice.

- a well coordinated collaboration between research centres and institutions of learning.

- Professional teacher support STEM mentoring programmes should be encouraged at the secondary school level.

7.0 CONCLUSION

This address examined the concept of STEM education, its practice/reforms in Nigeria, USA, China and Finland as well lessons for the Nigerian stakeholders in the education sector, particularly in this era of globalization and students' poor performance in STEM subjects at the SSCE level. It would seem that the poor performance does not give the Nigerian nation the assurance of becoming one of the top 20 economies by year 2020 talk less of meeting up with the target of EFA and MDGs by 2015. In the light of the present predicament facing effective teaching and learning of STEM subjects in schools, some ways forward were proferred which will serve as bases for further reforms in driving STEM education to greater heights. However, concerted efforts should be made to ensure that all these reforms are well addressed and implemented so as to improve upon students' performance in STEM subjects. In particular, government, school authorities, parents, teachers, students and all other relevant stakeholders in education should join hands to address the challenges that militate against effective implementation of STEM education programmes in Nigeria.

Appendix I

Table 1: Level of Students' Performance in NECO June/July SSCE with 5credits and above including English Language and Mathematics

Year	Total No. that registered for Examination	Total No. that sat for Examination	Total No. of Students with 5 Credits and above in English Language and Mathematics

			No. of Students	%
2009	1,201,262	1,184,907	126,543	10.67
2010	1,143,169	1,132,357	105,989	9.36

Appendix II

Table 2:

Level of Students' Performance by Subjects in NECO June/July Senior School Certificate Examination from 2009 – 2010

SUBJECT	YEAR	CANDIDATES REGISTERED	CANDIDATES THAT SAT	CREDIT PASS (AI – C6)		PASS (D7 – D8)		FAIL (F9)	
				TOTAL	%	TOTAL	%	TOTAL	%

MATHEMATICS	2009	1,199,644	1,163,689	316,049	27.15	455,955	39.18	264,486	22.72
	2010	1,143,169	1,113.177	285,146	25.62	512,209	46.01	249,562	22.42
FURTHER MATHEMATICS	2009	29,614	25,038	3,314	13.24	13,887	55.46	6,196	24.75
	2010	28,706	23,500	2,597	11.05	14,439	61.44	5,348	22.76
ENGLISH LANGUAGE	2009	1,200,398	1,168,546	273,279	23.38	538,091	46.04	229,356	19.62
	2010	1,143,169	1,116,195	245,890	22.03	599,911	53.75	203,875	18.27
LITERATURE-IN-ENGLISH	2009	312,451	290,935	17,066	5.87	166,778	57.32	67,004	23.03
	2010	302,243	283,748	13,315	4.69	183,739	64.75	67,263	23.71
BIOLOGY	2009	1,190,881	1,158,141	501,968	43.34	267,119	23.06	263,038	22.71
	2010	1,137,906	1,110,753	502,677	45.26	316,249	28.47	225,055	20.26
PHYSICS	2009	414,291	401,766	133,419	33.21	143,839	35.80	8,035	20.67
	2010	417,532	407,065	126,939	31.18	179,358	44.06	76,683	18.84
CHEMISTRY	2009	415,497	402,785	155,434	43.34	121,398	30.13	84,607	21.00
	2010	418,800	407,899	154,956	37.99	152,230	37.32	76,332	18.71
APPLIED ELECTRICITY	2009	974	812	46	5.67	661	81.40	54	6.65
	2010	1,138	1,015	1	0.01	808	79.61	200	19.70
TECHNICAL DRAWING	2009	11,699	8,923	3,850	43.14	2,740	30.70	1,992	22.32
	2010	12,982	10,178	4,336	42.60	3,342	32.84	2,287	22.47
AUTO MECHANICS	2009	276	226	101	44.69	82	36.28	37	16.37
	2010	256	240	33	13.75	155	64.58	49	20.42
WOODWORK	2009	831	719	0	0	465	64.67	251	34.91
	2010	872	792	5	0.63	640	80.81	125	15.78