DEVELOPING A QUALITY SCIENCE, TECHNOLOGY, ENGINEERING AND MATHEMATICS (STEM) TEACHER EDUCATION PROGRAMME THAT INTEGRATES INDIGENOUS KNOWLEDGE BASED SYSTEMS

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INTRODUCTION

I would like to commence this presentation by expressing my sincere gratitude to the entire management, staff and students of the Federal College of Education (Technical), Bichi for organizing this important conference. Permit me also to single out the organizers of this conference particularly the conference organizing committee under the chairmanship of Mr. Madu, Cletus Ifeanyi to present a lead paper at this important occasion.

I consider this conference important in two folds; firstly, it provides me with an opportunity to echo my “cries” that the woeful failure of our nation to conceive and implement a quality STEM teacher education programme is the root cause of students’ lack of interest in STEM education and or course, underachievement among those students that opt to study STEM education across all levels of our educational systems. By extension, it is responsible for the present nation’s underdevelopment. I wish to further argue that the dream of the nation to be among the top twenty economies in the world come 2020 will be a mirage if there is no STEM quality teacher education programme in place.

Secondly, the theme of the conference is quite appropriate. This is because an effective STEM teacher that is well grounded in pedagogy particularly in the use of indigenous
instructional strategies in the classroom is most likely going to promote students’ interest to opt for STEM education as well as inspire in them higher achievement. It is also my humble believe that the failure of the nation at independence to evolve a STEM teacher education programme that integrates indigenous and modern teaching strategies is largely responsible for the country’s poor showing in STEM education and socio-economic development among nations of the world despite its huge human and natural resources. This is because nations such as the republic of China that have integrated indigenous knowledge based systems in its STEM education are reaping its benefit.

This presentation focuses on how a quality STEM teacher education that integrates indigenous and modern instructional strategies could be conceived and implemented leading to the production of an effective teacher well grounded in content knowledge as well as in both indigenous and modern instructional strategies. The paper begins by addressing the following related issues:

- STEM- its meaning, purpose and nature of its curriculum.
- Status of STEM education in Nigeria.
- Status of STEM teacher education in Nigeria.
- Indigenous knowledge based systems – its meaning, nature and purpose.

**STEM- ITS MEANING, PURPOSE AND NATURE OF ITS CURRICULA**

**What is STEM education?**

There are no acceptable definitions of what constitute STEM education and what are excluded out of it. Various definitions have been canvassed by experts, organizations and nations mainly based on its goals and objectives. The following are sample of definitions:

- California Department of Education (20120 defines STEM as a means of identifying individual subjects, a standalone course, a sequence of courses, activities involving any of the four areas of STEM, a STEM-related course or an interconnected or integrated programme of study.
The House of Lords Select Committee on Science and Technology, (2012) sees STEM education as encompassing a group of disciplines that teach skills required for high-tech economy.

STEM education is an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply science, technology, engineering and Mathematics in contexts that make the connection between school community, work and the global enterprise enabling the development of STEM literacy and with it, the ability to compete in the new economy. (Morrison, 2006 and Tsupros, 2009).

Lartz Jr., (2009) contends that STEM education is greater than an interdisciplinary paradigm but trans-disciplinary in that it offers a multifaceted whole with greater complexities and new spheres of understanding that ensure an integration of discipline.

This is supported by the fact that new innovations and inventions today tend to be made at the boundaries of the four disciplines that constitute STEM, where they naturally overlap. For example, biochemistry, biomechanics, bioengineering, biophysics and biotechnology are representatives of the discipline we know as Biology.

STEM is an assemblage of practices and processes that transcend the disciplinary lines and from which knowledge and learning of a particular kind emerges (Jean and Susan, 2012).

THE PURPOSE OF STEM EDUCATION

The general aim of STEM education is to prepare students:

- For successful employment, post secondary education or both that require different and more technically sophisticated skills including the application of Mathematics and science skills and concepts and

- To be competent, capable citizens in our technology-dependent, democratic society.

STEM plays an important role in the socio-economic development of all nations. With globalization taking deep roots in world affairs, economic competition is being fiercer. This is
precipitated by the fact that advanced knowledge is becoming widespread and low cost labour readily available. This has resulted in the creation of emerging markets of especially the BRICS nations – Brazil, Russia, India, China and South Africa who now compete with developed nations. The emergence of these nations is believed to be due to their ability to develop, nurture and sustain an excellent STEM education. Therefore, for any nation to survive this fierce economic competition, its economy must be driven by STEM education as defined above. The United States of America responded to the challenges posed by emerging markets by coming up with various reforms in its STEM curricula to overcome this global competitiveness. Despite this effort, the USA government was warned in a most recent report in 2007 titled “Rising above the gathering Storms: Energizing and Employing America for a Brighter Future” of the inherent weakness in its STEM education programme that threatens national prosperity and power. Who does this report refer to as the gathering Storms? To me, they are certainly the BRICS nations.

A nation with a labour force without a rich supply of STEM skilled individuals will face stagnation or even declining wealth by failing to compete in the global economy, where discovery, innovation and rapid adaptation are necessary elements for success. The crop of scientists, engineers, technologists and mathematicians that could overcome this stagnation or declining of wealth and promote sustained economic growth can only be provided through functional STEM education. According to Morrison, “(2006), the major function of STEM education is to produce students who should be:

- Problem solvers
- Innovators
- Inventors
- Self-reliant
- Logical thinkers
- Technologically literate
WHAT IS THE NATURE OF STEM EDUCATION CURRICULUM?

A STEM education curriculum should strive to teach not only science and mathematics, but also technology and engineering components. In designing a STEM curriculum, the following elements should serve as a guide:

i. It should be standard driven – it should be built on best practices.

ii. Understanding by Design (UbD) – it should be based on the three stages advocated by the UbD i.e. desired Results, Assessment Evidence and Learning plan.

iii. Inquiry based teaching and learning.

iv. Problem-based learning (PBL) – is a student instructional strategy.

v. Performance-based teaching and learning performances-based teaching, learning and assessing has been shown to improve students’ achievements.

vi. 5E teaching and learning and Assessing Cycle 5Es- Engagement, Exploration, Explanation, Elaboration and Evaluation. It has been shown to enhance mastery of subject matter, increased ability of scientific reasoning and positive increases in cultivating interests and attitudes about Science (Lawson, 1995).

vii. Digital curriculum integrated with digital teaching technologies – this affords the opportunity to deliver curriculum to students in non-task specific rubrics. Assessment here should largely be non-traditional i.e. authentic. In this assessment format, students are required to construct, demonstrate or perform tasks (Doran et al., 1998).

THE STATUS OF STEM EDUCATION IN NIGERIA

The National Policy on Education (2004) spelt out the guidelines of STEM education in Nigeria which are meant to develop and promote the teaching and learning of STEM subjects or disciplines at various levels of education as follows:-

- At the Primary School (lower basic) – STEM subjects include Mathematics, Science, Agricultural Science, Physical and Health Education, etc. the teaching methods to be employed shall be practical exploratory and experimental methods.
At the Junior Secondary School (upper basic), the STEM subjects include Mathematics, Basic Science, Basic Technology, Computer Education, Agricultural Science, Home Economics, etc. the method of teaching is largely through guided inquiry approach. Youth clubs such as JETS, organizations and school societies serve as important instruments in enhancing character training and mental development.

At the Senior Secondary School level (post basic), the STEM subjects offered by students include Mathematics, Biology, Chemistry, Physics, Agricultural Science and technical subjects such as Auto-mechanics, Electronics, Metal work, etc.

At the tertiary level, STEM education shall be encouraged through greater expenditure on university education on STEM disciplines and deliberate admission policies such as 60:40 ratios in favour of STEM courses. In addition, STEM-based institutions such as polytechnics, monotechnics and trade centres shall be established.

The strategies employed by the government to ensure the successful implementation of the policies at various levels of education were as follows:-

- The government provides educational resources such as basic health scheme, library, counselling, educational resource centres and provision of qualified specialist teachers.
- At the secondary schools, STEM education shall be free, universal and compulsory up to the end of upper basic.
- The introduction of STEP-B project (Science, Technology Education Project) which is a World Bank assisted project set-up to enhance the production of more and better qualified science and technology graduates at the post basic levels as well as enhance quality and more relevant researches at the universities and research institutions.
- Technology transfer and indigenization of technology.

It is obvious that the STEM education policy in Nigeria did not take into consideration the key elements outlined in 2.3 in developing STEM curricula. For example, the Basic Science and Technology curricula at the upper basic level have undergone little or no change at all; they are merely “old wines in new bottles”. In addition, the STEM education is not interdisciplinary in its approach especially at primary and secondary school levels. Besides factors that stood
against the provision of quality and greater access to education at all levels such as poor funding, lack of qualified teachers, dilapidated buildings and absence of laboratories are on the increase, therefore, the dismal outcomes being recorded at all levels of the country’s educational system should surprise no one.

After about a decade of implementation of the reforms in STEM education, the outcome of the evaluation from the NECO and WAEC results showed the implementation is far from being successful. The index used at the national level is the number of candidates who obtained 5 credits and above including English and Mathematics. NECO June/July SSCE for 2009 and 2010 revealed that 126,543 (10%) and 105,989 (9.36%) candidates respectively had 5 credits and above including English and Mathematics. In this result, the performance in core STEM subjects may be much lower when compared with non-STEM subjects. What is the major factor that is responsible for poor performance in STEM subjects at the senior secondary school level? Teacher quality has been described as the most important key to improving pupils’/students’ learning achievement (Olaofe, 2010). It is more strongly related to academic performance and achievement than any other variables such as reduced class size, funding, increase in teachers’ salaries and huge financial and infrastructural investment (Darling-Harmond, 2010). Moreover, the national policy on education states that “No nation rises above the quality of its teachers”.

INDIGENOUS KNOWLEDGE BASED SYSTEMS - ITS MEANING, NATURE AND PURPOSE

What is indigenous knowledge based systems?

Several schools have provided various definitions of Indigenous Knowledge based Systems (IK), but according to Battiste, (2005) its meaning and definition can best be understood by people who practice them. Below are samples of definitions of IK:

- Indigenous knowledge is commonly understood to be the traditional knowledge or local knowledge of the indigenous peoples (Nakashima, Prott and Bridgewater, 2000) that is unique to that particular culture or society.
• IK is generated and transmitted orally and freely (Brush, 2009).
• The United Nations (UN) view IK as encompassing all forms of knowledge-technologies, know-how skills, practices and beliefs that enable a community to achieve stable livelihoods.
• IK is mainly of a practical nature particularly in the field of agriculture, fisheries, health, horticulture and forestry (Australian Academic and Research Libraries, 2005).
• It is the basis for local level decision making, education, natural resource management and a host of activities for sustainable development (World Bank, 1997).
• “Local and indigenous knowledge” refers to the cumulative and complex bodies of knowledge, know-how, practices and representations that are maintained and developed by peoples with extended histories of interactions with the natural environment (UNESCO, 2012)

These cognitive systems are part of a complex that also includes language, attachment to place, spirituality and worldview. Many different terms are used to refer to this knowledge, these include:

- Traditional ecological knowledge (TEK)
- Indigenous knowledge (IK)
- Local knowledge
- Rural peoples'/farmers' knowledge
- Ethnobiology/ethnobotany/ethnozoology/ethnopharmacology
- Folk science
- Agroforestry

Going through the above definition, it is apparent that IK is imbued with all forms of global knowledge and hence it should be recognized, valued and appreciated (Ellen and Harris, 1996). Despite all these efforts by international scholars and the international organizations such as the UN, International Labour Organization and the World Bank to recognize and value the role of IK in sustaining the life of millions of people globally, it still remains devalued, when contrasted with the Western Knowledge (WK), as unevaluated and
untested data set for the scientific frameworks (Australian Academic and Research Libraries, 2005). In the recent years, there is increasing awareness and global recognition of Indigenous Knowledge systems as a growing field of inquiry (Battiste, 2005) and as a distinct legitimate and valuable source of knowledge (Australian Academic and Research Libraries, 2005).

From these definitions, it could be seen that IK contains a lot of STEM education that could be integrated into modern or Western education. In Nigeria, IK is largely regarded and treated as an informal knowledge and there has been little attempt to integrate the two, especially in our educational system. This perhaps explains the lack of interest to opt for STEM education among many students because of its perceived difficulties and the present underachievement in STEM education among the students that offer it.

THE NATURE OF INDIGENOUS BASED SYSTEM

Indigenous knowledge based system just like any other forms of knowledge have distinctive features. However, it also possesses certain features that it shares with other form of knowledge. IK takes the forms of stories, songs, folk lore, proverbs, cultural values, rituals, community laws and local languages (Barnhardt and Kawagley, 2005) as well as agricultural practices including the development of plant species and animal breeds. Indigenous knowledge is characterized by cumulative, holistic and practice oriented; that is, it is not fragmented into categories or abstractions. Indigenous knowledge is place-based in that it is inseparably linked to a specific location. Indigenous systems of knowledge recognizes the significance of other that rational modes of knowing such as visions, dreams and intuitions. Indigenous knowledge is expressed and transmitted through language (Oral History, stories, songs, narratives, place names), social organizations, everyday and ceremonial practices, observations, values, institutions and laws. The intergenerational accumulation and communication of knowledge is central in indigenous system of knowing. Indigenous knowledge is mainly acquired by long term observation and experience.

The distinctive features of IK and pedagogy of learning are by observation and doing, learning through authentic experiences and individualized instructions and learning through enjoyment. The pedagogy of IK accepts students’ cognitive search for learning processes that he or she can
internalize. IK is both empirical and normative (based on social values) and is embodied in songs, ceremonies, symbols and art works.

THE IMPORTANCE OF INDIGENOUS KNOWLEDGE BASED SYSTEMS

From its different definitions and nature, IK is useful in sustaining the life of millions of people throughout the world even in the face of challenges it is facing from modern or Western science which is exacerbated by globalization. It plays a great role in many facets of human life such as agriculture, forestry, fisheries, health and education; and above all in decision making processes

Every traditional society of the world possesses a form of science or technology which is employed in indigenous practices geared towards the satisfaction of basic needs. These informal practices (Oguniyi 1980; Samuel, 1986) may be useful even in the face of modern science and technological advancement. Instead of rendering them obsolete in these societies, they can be refined and integrated in the knowledge and techniques of formal science. This is because they constitute direct experiences with the immediate environment and with the natural world; they may be very useful to teachers and learners in enriching classroom STEM education experiences thereby facilitating teaching and learning. Howes, Jones and Josenthal (2004) remarked that classroom bound activities of science teaching should make room for practices that help teachers and students to connect more deeply to each other and the rest of the world. Formal and informal sciences interact with one another. In Nigeria, both are practiced in different contexts and their linkage is advocated (Majeha, 1992; Animola 1992; Seweje 2000). The question is how can IK be integrated in STEM education in a highly diverse situation like Nigeria? I wish to submit that it is quite possible, but with certain limitations, this is better that the present practice where we have decided to throw away the bathe water together with the baby.

STATUS OF STEM TEACHER IN NIGERIA

Weaknesses of STEM teacher education in Nigeria

Quality STEM teacher education is central to the provision of quality STEM education despite the numerous reforms like inclusive teacher education, massive distance education, directional
shift from Grade II to Nigerian Certificate in Education and Teacher Registration Council, the production of quality STEM teachers has continued to elude Nigeria. This is as a result of inherent weaknesses in the country’s STEM teacher preparation programmes. The following are some of the weaknesses associated with STEM teacher education programme and the profession.

- Low status is accorded to the teaching profession, therefore the programme attracts few and weak students that do not qualify for other STEM professional courses, the JAMB “leftovers”.

- STEM teacher education curriculum sacrifices a lot of STEM subject contents including practical associated with these contents for education courses. The education courses also contain less of pedagogy. This explains why STEM teacher education products are not strong in pedagogical content knowledge (PCK).

- The present STEM teacher education curriculum in Nigeria does not meet the minimum requirement for a true STEM curriculum (see 2.3) and does not take into consideration indigenous knowledge based systems. In addition, the STEM teachers are not trained in the use of indigenous instructional strategies in the classroom.

- Though NCE is the minimum qualification for teaching at both primary (lower basic) and junior secondary (upper basic), its nature does not prepare the graduates for teaching at these levels except products of Primary Education Studies and Primary Science who could teach at primary schools and that of Integrated Science at the junior secondary school.

- It has been shown that the current restructuring of STEM subjects at the NCE level in which key STEM courses (Physics, Chemistry and Biology) will be replaced by subjects such as basic Science and Basic Technology could lead to serious decline in the enrollment of prospective teachers into STEM subjects (Peni 2011). The Kwara State College of Education, Oro used for pilot testing in restructuring suffered a serious setback in students’ enrollment.

- There is mounting public outcry on the poor quality of NCE teachers including STEM teachers (Akale, 2006 and Junaidu, 2011).
TOWARDS A QUALITY STEM TEACHER INTEGRATION PROGRAMME THAT INTEGRATES INDIGENOUS AND MODERN INSTRUCTIONAL STRATEGIES

A suggested model for STEM teacher education programme in Nigeria

Having identified the existing pit falls in the present teacher education programme, it should be replaced by a robust programme proposed by Lawal, Dogara and Amadu, (2005). The overall training presented in Figure I shall be a five-year degree programme in all relevant STEM subjects. The programme shall proceed by coming up with STEM curricula in all subjects that satisfy the minimum international standards. In addition, the STEM curricula should identify, integrate useful and relevant indigenous based systems prevalent among the diverse societies in Nigeria.

The first four years, is the pre-clinical, during which students are exposed to Pedagogical Content Knowledge (PCK). The pedagogy should consist of both indigenous and modern instructional strategies. The STEM student teacher should in addition be rigorously trained on the curriculum they will be teaching, environment for learning professional practice, nature of STEM, social context of STEM and the use of authentic and traditional assessments. Above all, the STEM student teachers should be trained to have increased sophistication in attitudes, professional knowledge and interpersonal interactions.
A FIVE YEAR MODEL FOR STEM PRE-SERVICE TEACHER PREPARATION

**Pre-Clinical**

- University of College of Education (UCE)
  - conventional/technical B.Sc in STEM education subjects

**Clinical**

- Professional Development Schools (PDS)
  - primary and secondary schools
  - Schools Industry linkages (SIL)
  - Industries provide industrial experience

- National Commission for Teacher Education (NC TE)
  - Accreditation of teacher education

- Teachers Registration Council (TREC)
  - Licensing and discipline

- Professional Practice (PP)
  - Primary and Secondary Schools
  - Universities of Education
  - Universities
  - Polytechnic

- Faculties of Education in Universities
  - Postgraduate training and research

**OTHER COMPONENTS OF THE MODEL**

- Minimum entry qualification for the programme is 5 credits in STEM subjects including English and Mathematics.

- Exposure of student-teachers to schools and industry linkages relevant to teaching and learning of STEM subjects.

- Student-teachers report back to university for graduation and certification.

- Licensing and discipline by the Teachers’ Registration Council (TREC).

- The STEM teacher education are to be run in Universities of Education.

- The minimum entry qualification for teaching is a degree; a Masters attracts a promotion and higher scale at the point of entry.

- The present Federal Colleges of education are to be converted into Universities of Education.
• Faculties and institutes of Education should concentrate on postgraduate training and other capacity development programmes.

• National Commission of Teacher Education will be the body responsible for accreditation of courses.

ANTICIPATED PRODUCTS – QUALITY OF STEM TEACHERS FROM THE TRAINING IN THE SUGGESTED MODEL

Quality STEM teachers could be produced provided the following are made available as outlined by Olaofe, (2010):

• Developing a STEM curriculum at all levels of our educational systems that meet minimum international standards as well as incorporates it in indigenous knowledge based systems.

• Setting up a national benchmark on what a qualitative STEM teacher should know and be able to know.

• National STEM teacher quality assurance assessment instrument.

• Continued capacity building of STEM teacher for quality teaching.

• National examinations for STEM teacher educators and learners to measure how far or near they are from the national benchmark.
Anticipated products- quality STEM teachers in the suggested model

- Competence in content knowledge of Modern STEM & indigenous STEM such as ethnobiology, ethnophysics, ethnochemistry, ethnomathematics etc.
- Competence in Pedagogical knowledge of modern & Indigenous STEM instructional strategies such as folklores, cultural practices, artworks etc.
- Demonstrate genuine concern on the achievement or otherwise of his/her students
- Demonstrate capability to formulate and administer both traditional and authentic assessment methods in the context of modern and indigenous knowledge of the students
- Demonstrate competence in lesson delivery, interactive patterns and styles through the use of good command of language of instruction/indigenous language
- Demonstrate desirable attitudes to his/her job based on modern and indigenous knowledge particularly attitudes such as curiosity, honesty, hard work etc.
- Production of quality STEM products- employable, self reliant engineers, scientists, technologists, mathematics etc.
- Economically secured, stable and prosperous nation

Quality of Effective Teacher radiates the following competencies:
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