PEDAGOGY AND ANDRAGOGY: MEETING POINT IN CONCEPTS AND MISSING LINK IN THE PRACTICE OF SCIENCE, TECHNOLOGY, ENGINEERING AND MATHMATICS (STEM) TEACHER PREPARATION IN NIGERIA

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Abstract

Science, Technology, Engineering and Mathematics (STEM) education can be described as the foundation for development education since modern development is largely steered by science and technology. Technical Vocational Education and Training (TVET), as a special area in STEM, is responsible for preparing the personnel to translate science and mathematics into consumable products. As technology is founded on science and mathematics, so also must effective TVET education be built on effective basic science and mathematics education. The combined effects of the unfortunate inabilities of these essential subjects in Nigerian education system to produce the desired impact are major culprits in the perpetuated techno-economic dependency of Nigeria and the high rate of poverty among her citizens. Some perceived shortcomings in teacher preparation with implications for curricula implementation for these subjects are seen as contributing factors to the inability of STEM education to catalyse development in Nigeria. This paper, underpinned by the need to explore the relationships between teacher preparation, teacher readiness and effective curricula implementation, after a brief introduction, gives an overview of the place of STEM in technological and economic development. It then highlights the roles of STEM teachers in effective implementation of STEM curricula as well as STEM teacher competencies required for effective teaching. It further highlights conceptual relationships between pedagogy, andragogy and teacher preparation. Overviews of international best practices in teacher preparation are provided and then the perceived comparative weaknesses of STEM teachers' *preparation in Nigerian are discussed. Finally, approaches to enhance the Nigeria trained STEM teachers competencies are suggested.*

Introduction

Well trained human resources in the form of human capital are an essential asset to any society, being instrumental to development by their responsibility for the manipulation of all other factors of production. Human capital development hence is usually a priority policy issue for any nation. However, trained personnel in Science, Technology, Engineering and Mathematics (STEM) hold an essential position in the pool of a nation's human capital resources, particularly the teachers. All the fields of STEM have some relationships both in contents and as tools for development. Science, according to Science Council (2009), is the pursuit and application of knowledge of the natural and social world following a systematic methodology based on evidence while Technology is defined as the modernization of the natural environment in order to satisfy human needs and wants (ITEEA, 2007 in Dugger Jr, 2015). Similarly, the Accreditation Board for Engineering and Technology (ABET) (2002 in Dugger Jr, 2015) defines engineering as the profession in which a knowledge of the mathematical and natural sciences gained by study, experience and practice is applied with judgement to develop ways to utilize, economically, the materials and forces of nature for the benefit of mankind. Lastly, the Cambridge Academic Content Dictionary (2017) defines Mathematics as the study of numbers, shapes, and space using reason and usually a special system of symbols and rules for organizing them.

The level of development of any nation largely depends on the effective use of the specialized knowledge, skills, and competences in these STEM fields to harness and utilize its natural resources (Idris &Rajuddin, 2012). But engineering is rooted in mathematics and science, and is described as 'a three legged stool' that relies on science, mathematics and techné; the word technéas being the creative abilities that distinguish an engineer from a scientist, which enables the engineers to design, to make, to conceive and to actually bring to fruition (Idris &Rajuddin, 2012).

STEM education therefore occupies a special place in the educational systems of nations as the foundation for development because modern development is largely steered by science and technology (Grijpstra, 2015). Socio-economic and technological transformation of any nation, as exemplified in the accelerated turnaround of the fortunes of the Asian Tiger nations, depend largely on the level of its STEM education. This too affirms that the low level and rate of technological and economic development in

Nigeria in the face of abundant natural resources is consequent, to a large extent, upon ineffectiveness of her STEM education (Ajimotokan et.al, 2010 in Idris &Rajuddin, 2012).

In order to stimulate and foster sustainable development and make impact in the rapidly changing globalized technological and economic systems, Nigeria, through effective STEM education, need to develop her capacity to adapt and operate a complement of educational, scientific, technological and economic systems that are sustainable and also capable of empowering her for active participations in contemporary development domains, both domestically and globally. Science and technology, however, are dynamic: changing continuous, due to innovations and new discoveries. Manpower trainers are therefore always up and doing, through research and collaborations, to keep workers' knowledge and skills (including teachers') in tune with such changes.

In Nigeria however, the effects of changes and innovations in science and technology, which are seen to drive many other economies to the skies, are little felt or non-existent. The inability of STEM education to develop the much needed competent technical manpower for the country's technological and economic transformation is largely due to poor quality of STEM education, particularly teachers'. Adedeji (2018) observes that the products of current mathematics education in Nigeria are not good enough in terms of teachers' quality - subject mastery, professional competence and pedagogical acumen among others. Aina and Keith (2015) affirms that the engineers and engineering technologists graduating from the universities and polytechnics do not possess the competencies required for cutting edge technologies in industries, and need retraining at additional costs to be employable. The ripple effects of such challenges are grievous as nearly everything today, from economic, educational, environmental, socio-political, to health related activities, are becoming increasingly science and technology driven. This places great demands on STEM education. It is however a common sight for teachers to turn science and TVET lessons in the schools to reading and explanation sessions or students to walk out of mathematics lessons; teachers often lack the needed competencies to create conducive learning environments, arrest learners' attention, arouse their interests and vary their lessons presentations to suit the nature of instructional/learning contents and situations.

The problems of ineffective teaching are often beyond the problems with teachers' initial training. A continuous outlook for the best tools and tactics for educating children often create needs for teachers to change tools, curriculum and seek to adapt emerging best practices, which if not backed by adequate retraining, leaves many teachers bewildered trying to figure out what to do. Also some schools are resistant to change and teachers with ideas about new learning trends may not receive support and funding to adopt them.

In view of the place of teachers in implementation of STEM education programmes, it is appropriate to seek for ways to improve the quality of their preparations to enhance their readiness for the ever changing work demands. This paper thus juxtaposes the current practices of STEM teachers' preparations in Nigeria with some identified best practices to expose the weaknesses and improvement needs in the Nigerian practices. Nigeria urgently needs a revitalised STEM teacher preparation programmes to enhance the quality of the entire STEM education system. This will help to create a pool of high quality scientific and technical manpower, reduce unemployment by turning the large numbers of unemployable youths into a formidable workforce, and stimulate technological and economic growth.

The Place of Stem in National Technological and Economic Development and Wellbeing

STEM is useful to human life to the extent that it will be very difficult to predict what existence will be like without it. In this vein, **Suchenski (2015) declares that STEM** includes everything we experience, from the natural world to agriculture, communication, healthcare transportation, etc.; emphasising that it pervades every aspect of peoples' lives and is the key to a better tomorrow. However, it suffices to mention a few ways in which STEM is helping to sustain human life and development (as articulated in Odigiri, Ozoji& John, 2019):

i. Health, Water and Sanitation – helps in the prevention, control and treatment of diseases and ailments.
ii. Food Security (Agriculture) – help in the development of improved seeds/seedlings and animal, mechanized agriculture and food processing
iii. Natural Environment – give explanations to many naturally occurring phenomena which improve man's understanding and enable people to live more comfortably and friendly with nature.
iv. Information and Communication – improves the speed, reach and nature of communications with the use of computers, radio, television, etc.
v. Economic and Poverty Reduction/Wealth Creation – improves the exploration, processing and utilization of natural resources for production of goods to satisfy human needs; create new employment opportunities and transform ways businesses are conducted.

vi. Education – facilitates new ways of teaching and learning; uses information and communication technologies (ICTs) to diversify instructional delivery, aid learning and improve learning achievements.

Roles of STEM Teachers in Effective Implementation of STEM Curricula

Evidence shows that effective teachers are the most important in-school contributors to student learning (Brabeck& Worrell, 2014). Generally, teachers are facilitators of learning; they offer guidance, direction, support and leadership to learners during the teaching/learning processes. The teacher model, coaches, assesses and gives feedback to support learning, and uses the last two for summative evaluation and for certification. The nature and extent of involvement of the teacher depends on several factors such as the type of instructional/learning contents and environment, learner abilities, attitudes, etc.

STEM Teacher Competencies for Effective Teaching and Assessment

Best practice teaching in STEM subjects leads students to encounter learning experiences the same way experts do at their works. For instance, science students learning scientific enquiry should be able to relate what they do to scientists' work and be able to answer the question of how what they do is like what scientists do in their work (National Science Teachers Association (NSTA), 2005). For teachers to be able to teach and assess scientific inquiry skills therefore, they should be competent scientists themselves, with the capabilities to carry out what they purport to teach and not just to read and tell their students about what scientists do. So also it is with all the other STEM subjects; TVET, engineering and mathematics teachers should be able to carry out the projects they give to their students, using the same tools and procedures, etc. Brabeck and Worrell (2014), corroborating this position, affirms that the new single accreditor of teacher-preparation programs in the USA, the Council for the Accreditation of Educator Preparation(CAEP), evaluate programs based on what teacher-candidates can do.

Quality assurance agencies in different countries thus spell out competencies required by teachers in such programmes. They are usually customised to suit the objectives and levels of specific programmes. An example of typical competencies for TVET trainers/teachers and assessors training providers in Bangladesh (Bangladesh TVET Reform Project, 2012), are spelt out in the Competency Standards for TVET Trainers/Teachers and Assessors. Such documents also specify details of the knowledge content for each unit of competency to guide training providers. The units of competency in the Bangladesh typology are listed below:

i. Work effectively within Bangladesh TVET sector
ii. Promote inclusive learning in a Competency Based Training and Assessment (CBT&A) environment
iii. Apply Occupational Safety and Health (OSH) practices in a CBT&A environment
iv. Use information technology (IT) to support learning
v. Maintain training equipment and facilities
vi. Maintain and enhance professional practice
vii. Maintain and enhance technical competency
viii. Design and modify CBT learning materials and resources
ix. Plan and organize competency-based training sessions
x. Deliver competency-based training
xi. Design competency-based assessment
xii. Organise and conduct competency-based assessment
xiii. Design and develop competency-based learning programs
xiv. Validate competency-based assessment
xv. Facilitate training of TVET teachers and trainers
xvi. Conduct training need analysis (TNA)
xvii. Coordinate training and/or assessment arrangements for apprenticeships
xviii. Evaluate competency based training and assessment (CBT&A).

In mathematics, Blomeke and Delaney (2012) identify a specific approach that is important in the universe of approaches to mathematics called Mathematics Pedagogical Content Knowledge (MPCK). It encompasses the subject-related knowledge for teaching known as an amalgam of content and pedagogy: a form of professional understanding that is uniquely the province of the teachers, comprising mathematics curricular knowledge, knowledge of planning for mathematics teaching and learning [pre-active], and enacting mathematics for teaching and learning [interactive]. Under these three main grouping are several more subscales as follows:

1. Under the mathematics curricular knowledge:
   i. Establishing appropriate learning goals
   ii. Knowing about different assessment formats
   iii. Selecting possible pathways and seeing connections within the curriculum
   iv. Identifying the key ideas in learning programs
   v. Knowledge of the mathematics curriculum
   vi.

2. Under the knowledge of planning for mathematics teaching and learning [pre-active]:
    i. Planning or selecting appropriate activities Choosing assessment formats
    ii. Predicting typical student responses, including misconceptions
    iii. Planning appropriate methods for representing mathematical ideas
    iv. Linking didactical methods and instructional designs
    v. Identifying different approaches for solving mathematical Problems
    vi. Planning mathematics lessons; and

3. Under the enacting mathematics for teaching and learning [interactive]:
    i. Analysing or evaluating students' mathematical solutions or arguments
    ii. Analysing the content of students' questions
    iii. Diagnosing typical student responses, including misconceptions
    iv. Explaining or representing mathematical concepts or procedures
    v. Generating fruitful questions
    vi. Responding to unexpected mathematical issues
    vii. Providing appropriate feedback

Similarly, long lists specifying competencies required by teachers of science for their numerous roles in effective teaching at different levels of the education system in the USA are prepared in conjunction with relevant stakeholders like NSTA. These competencies could be of great use in variety of ways during programme designs, curriculum development and implementation as well as assessments.

Conceptual Relationships between Pedagogy and Andragogy with Teacher Preparation

Andragogy, a concept made popular by Knowles, is defined as the art and science of helping adults learn as against pedagogy as the art and science of teaching children (Clardy, 2005). Specifically, andragogy was conceived on the assumption that adults have different learning characteristics in terms of attitudes, interest, purposes, etc. as well as requirements in teaching/learning principles, techniques and educational procedures than children (Clardy, 2005). There was much debate on whether andragogy is a theory, method, technique or a set of assumptions; doubts which stemmed from differing philosophical viewpoints in its classification and value for adult education (Delahaye, Limerick & Hearn, 1994).

Initially, Knowles posited andragogy against pedagogy, where pedagogy was best for children and andragogy was for adults. However, he modified his views in his latter works so that both methods can be used either with children or adults, depending on circumstances. The adult expected to benefit from andragogic learning principles should be the person who occupies roles that have been traditionally defined as adult roles (such as parent or worker), and his concept of himself has changed from one of dependency to one of autonomy and self-directing; who perceives self as responsible for his/her life; in pedagogy however, the teacher guides and directs the leaner/learning (Delahaye, Limerick & Hearn, 1994; Pappas, 2013).

Since STEM teachers are to lead students to encounter learning experiences the same ways expert do at their works, they must be prepared ready to take such responsibilities. Teacher candidates are adults who have chosen career paths and are directing their focus on taking specific responsibilities at the end of training, can learn from andragogic principle, their training has to prepare them for real-world applications of their knowledge and skills with younger learners. For instance, science students learning scientific enquiry should be able to relate what they do to scientists' work and be able to answer the question of how what they do is like what scientists do in their work (National Science Teachers Association (NSTA), 2005). For STEM teachers to be able to teach and assess students' skills, they should themselves be competent practitioners of the skills, capable of demonstrating them during the teaching/learning processes. This implies that STEM teacher preparation programmes must adopt andragogic and pedagogic principles together, the former to facilitate adult teachers candidates' learning, and the latter to acquaint them with the strategies, techniques and principles they will need to use when they may have to teach younger students in secondary schools.

Overview of International Best Practices in Teacher Preparation

Best practices in education are educational practices that correlate with higher student performances. In whatever level and subject, they produce verifiable evidences of high quality results – performance and satisfaction on the parts of both learners and teachers. Based on evidences that effective teachers are the most important in-school contributors to student learning (Brabeck& Worrell, 2014), teacher education must prepare teachers for the most rewarding teaching strategies and techniques in their subjects to make teachers ready for teachings. The Western Washington University Center for

Instructional Innovation (n.d) listed some important best practices in teaching to include:

i. Engage students in active learning experiences
ii. Set high, meaningful expectations
iii. Provide, receive, and use regular, timely, and specific feedback
iv. Become aware of values, beliefs, preconceptions; unlearn if necessary
v. Recognize and stretch student styles and developmental levels
vi. Seek and present real-world applications
vii. Understand and value criteria and methods for student assessment
viii. Create opportunities for student-faculty interactions
ix. Create opportunities for student-student interactions
x. Promote student involvement through engaged time and quality effort

Generally, emphasis is placed on appropriate quality assurances of programmes adequacy and candidates' competency before certification and licensing. This is followed with continuous teacher professional development to ensure teacher readiness always to use best practices in teaching to bring out the best in students' learning outcomes (St Olaf College, 2017). Below are some exemplars of best practices in STEM teacher preparations:

i. *Science Teacher Preparation in USA*

Bachelor degree is the minimum qualification for teaching. Teacher training must be in an approved teacher preparation institution and candidate must obtain state or national license before he/she can practise. The entry level teachers' education usually, are specific for elementary, middle and secondary teachers, and involve courses in instructional theory and a major subject area, followed with an internship. Subsequently, teachers engage in continuous professional development to improve their teaching skills and/or acquaint them with new strategies/techniques and other innovations in teaching that are relevant to improve or change their teaching(St Olaf College, 2017).

ii. *TVET Teacher Preparation in Germany*

Germany can be seen as the technology hub of Europe and the arrowhead in the implementation of the Bologna Declaration (1999), at least in respect of TVET teacher preparation. Bologna Declaration (1999) represents the commitment by European countries to reform the structures and develop a coherent system of higher education which would be recognised in the competitive international domain in terms of high quality provision, enhanced transparency and ease of mobility within the European Union (Bunning &Shilela, 2006). The German typology can therefore represent what is generally expected in Europe, although there is no legal status attached to the Bologna Declaration to bind member states.

TVET teacher preparations vary across the country, between regions (states) and between training provider institutions, with some basic commonalities in practice and regulations by government agencies or government approved private agencies (Bunning &Shilela, 2006). Before the advent of Bologna Declaration, the practice involves a one strand dual preparation to a master's degree level, usually through a dual apprenticeship and school-based education system, resulting in double qualifications and certification in trade area and academics. The Bologna broke the single stand into two, allowing for certification with a bachelor's degree at the end of the first stand, allowing for practising with restrictions in responsibilities at that level, and opportunity to return for the second strand of training for a master's degree. The technical and vocational components of training are retained through the second stand to the end of the master's programme; students also undergo compulsory internship in the industries. Dual qualifications in trade and academics offer the advantage to fit into both the classroom and the industry, thus availing a two-way path for career choice, and also a guaranteed competence for effective teaching.

STEM Teachers' Preparation in Nigerian and **Perceived Comparative Weaknesses**

STEM teachers are expected to teach, facilitate and assess learning by leading students to encounter learning experiences the same way experts do at their works. **STEM teaching requires learning essential contents through the perspectives and methods of inquiry to allow learners derive meanings from experiences and construct their own knowledge.** The teachers facilitate learning through appropriate design of learning experiences involving them in modelling, coaching and scaffolding as may be necessary; adopting best practice teaching approaches such as identified in The Western Washington University Center for Instructional Innovation (n.d). Hence teacher training should prepare teachers to be competent to carry out these activities with proven expertise. None of these expectations can however be said to have been met in Nigerian classrooms, both during teacher trainings and in their practices.

Aina and Keith (2015) and Ogunmade (2005) found in their different studies that real science israrely encountered or experienced in most science classrooms in Nigeria. The typical situations they found is a focus almost wholly on what current scientists accept as explanations and science students only need to remember what teachers or textbooks say while most laboratory experiences are mere verification activities of what teachers and textbooks have indicated as truths about the natural world without time for students to design experiments that could improve human existence. These situations apply not only to science education, but to all the fields of STEM education. STEM teacher education most often rigidly follow prescribed procedures and processes to carry out perfunctory classroom activities to verify what "experts" say is truth. This type of teaching approach reduces learning in STEM fields, at best, to mere memorization of processes and procedures, usable only in similar situations later with little or no chances for transfer as is expected of knowledge and skills in all STEM subjects.

Teaching practices that have proven evidences of consistently high learning achievements are those that allow learners to search for and construct their knowledge, though under the guidance of a teacher. STEM teachers should be trained for such teaching by involvement in same processes during their trainings. An example of best practice STEM teacher preparation is the TVET teacher training in Germany where teacher trainees receive dual training involving apprenticeship in the industry along with academic education in schools, resulting in double qualification and certifications in trade and academics (Bunning & Shilela, 2006). Until the very recent professionalization of teaching in Nigeria, anybody that was willing could be a teacher; and even now, only the engineering field of STEM licenses members before they can practice, but most engineers practising as teachers do not qualify as professional teachers.

STEM teachers in Nigeria, who are therefore largely ill-prepared, are often seen to face numerous challenges in engaging in effective teaching of their subjects, either because of lack of mastery of curricula contents or of appropriate instructional strategies and techniques (Aina& Keith, 2015).Aina and Keith (2015) also confirm that many of the teachers handling sciences in secondary schools, for instance, specialize in science and not science education. Since teaching in Nigeria has been professionalized, all teachers are expected to be trained to qualify both as professional teachers and subject experts, at least for the levels they should be licensed to practice, as anything else must be in clear variance with best practices.

Conclusion

Evidences from literature and researchers' experiences show that programmes of STEM teacher preparations in Nigeria have not been meeting the competency requirements of teachers in their fields. However, in line with the fast growing trend of internationalization of educational and worker competency standards, particularly in STEM fields, it becomes urgent for

Nigerian government and all relevant stakeholders to look around - inward, outward and sideways, for necessary cooperation and collaborations to modify, modernise and move STEM teacher education in particular, and of course STEM education in general, to the international standards as the sure means to walk out from techno-economic dependency to an advantaged techno-economic competitor on the international domain.

Recommendations

In order to improve the quality and attain international standards of STEM teacher preparation in Nigeria for Nigeria, it is recommended that governments in partnership with the appropriate stakeholders should take the following measures:

1. Review STEM teacher education curricula to current cutting edge technological and pedagogic standards, with the support of relevant local and international partners;
2. Strengthen employer involvement in STEM education through a partnership framework that will offer attractive business prospects to the private sector;
3. Develop/adapt international competency standards for STEM teachers;
4. Encourage the formation of relevant professional bodies who will, in partnership employer groups and government agencies, aid in quality assurance activities;
5. Re-organise and refocus the Industrial Training Fund (ITF) towards technical linkage with the industry/employers for enhanced participations in curricula development teacher continuous professional development and funding for STEM education.

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