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REPOSITIOINING STEM CURRICULUM FOR EFFECTIVE TEACHING OF CHEMISTRY IN NIGERIA SECONDARY SCHOOLS TOWARDS ACHIEVING SUSTAINABLE DEVELOPMENT GOALS

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Abstract
Traditional/conventional teaching pedagogue usually adopted in teaching Chemistry in secondary school is teacher-centered. Teachers dominate the teaching-learning process thereby rendering learners passive. Learners produced by conventional method lack the hand-on skill and are considered unemployable by the industries that require such skill. This work reviews the traditional pedagogues in chemistry teaching and the problems inherent in the teaching approach. It also attempts to proffer alternative approach to chemistry teaching in the 21st century to imbibe in learners the skills and competence to cope with the competitiveness and drive the economy. Integrated STEM approach is recommended to be implemented in teaching chemistry to reposition chemistry for sustainable development in Nigeria to achieve the ultimate goal of national development.

Introduction

Despite her abundant natural and human resources, Nigeria, the most populous black nation remains a laughing stock among the committee of nations as a sleeping acclaimed giant of Africa, even after sixty years of self-rule. Nigeria was ranked the 103rd out of the 118 countries surveyed by UNESCO in 2015 Education for All Development Index, due to her poor funding of education. Presently, Nigeria remains a developing country with low economic, social, political, cultural and technological indicators (UNESCO, 2009). Nigeria economy is largely a dependent economy relying on importation of finished products from America, Europe and Asia. Apart from the devastating effect of importation on the country's Gross Domestic Product (GDP); it also takes the supposed job opportunities for the teeming unemployed youths abroad. No wonder the country youths' unemployment is high, quality of life is low and majority live below the poverty threshold.

Presently, countries in the world are categorized as: developed, developing, and less/under developed. The difference between the developed, developing and underdeveloped countries however rests on the ability of the developed countries to convert scientific ideas to usable technology while the developing and underdeveloped countries are yet to do so effectively (Gbamanja, 1991). The demand of skillful human capital in imparting scientific knowledge, values and problem solving has changed the education perspectives in the 21st century. The world continues to witness an unprecedented development and challenges in science and technology (Hassan & Ibrahim2018). Speedy and viable growth of a country can only be attained through scientific research, coherent application of STEM knowledge and skills (Okeke, 2008).

Science and technology drives the economy of a nation and the world at large. Science, Technology, Engineering and

Mathematics (STEM) are the cardinal wheels that advance sustainable development in developed nations of the world. Science, Technology, Engineering and Mathematics are some of the key subjects to study now because of the need for Nigeria to evolve the scientific and technological innovations needed to face the challenges of globalization and to build an evolving knowledge-based economy. In Nigeria, National Policy on Science and Technology which is an off-shoot of National Policy on Education had a 25-year target to create an independent, integrated and self-sustaining economy (Federal Science Technology of Nigeria, 1986). By implication, at the expiration of the target one would expect Nigeria to be self-sustaining by 2011. It becomes imperative to appraise the extent to which the current system of education in the country achieve this end and bring national development which is the ultimate goal of educational policy in Nigeria,

Today, it is a great concern that many graduates from Nigeria tertiary institutions are considered unemployable by industries due to their lack of hand -on skill and requisite knowledge that could make them cope in the labour markets. The Industrial Training Authority (ITA) reported that a lack of skilled labour, low technological uptake, inadequate investment in research, and out-dated educational materials in Nigeria have created a mismatch between graduate skills and labour market demands. Nigeria lives on transferred, borrowed, bought or even stolen technology as opined by Ugo and Akpoghol, 2016. In the real sense, graduates from STEM education must be equipped with sufficient skills that would make them self-dependent, prepare them to enter into job markets and progress well (Umar, 2019).

Economic Recovery and Growth Plan (ERGP) asserted that among the challenges that most urgently need to be addressed in Nigeria are limited STEM training, inadequate facilities at all levels of education, substandard tertiary infrastructure and a lack of high-quality Technical and Vocational Education and Training programme. Within the context of science education, Biology, Chemistry, Physics and Mathematics has been identified as a very important subjects and its importance in scientific and technological development of any nation has been widely reported (Ugo & Akpoghol, 2016). Chemistry is considered a core science that can permeate several areas of knowledge, such as Engineering, Health, Astronomy, Biology, and Geology, among others (Quadros et al., 2011).

As bedrock of modern technology, Chemistry plays a pivot role in national development. Its various products drive the economy of a nation. Its application in battery making, fertilizer production, textile production, plastic making, cement production, petroleum and petrochemicals, metallurgy and material science cannot be jettisoned. It helps in the characterization of matter and suggests it for appropriate use, based on its properties (Ayankoso & Odoje, 2020). However, some aspects of the chemistry curriculum specify hands-on-processes and skill acquisition, but, most students are not exposed to these real situations in our schools. In some schools, chemistry is not effectively implemented because there is no human capital, laboratories and workshops for practical work. Therefore, the curriculum policies and practices in secondary schools have some yearning gaps (Offorma, 2005). Efforts should be directed towards filling of the learning gaps.

Statement of Problem

The abstract nature of chemistry makes many learners find chemistry to be a difficult subject. Also, teachers find it pretty difficult to get time to provide additional support service to students to overcome their

learning difficulties in their weak areas. To achieve significant gains, active learning should be encouraged as opposed to the didactic lectures in order to enhance student learning continuously after missing fundamental concept (Redish et al., 1997). Active learning is facilitated through students' activities and by promoting student engagement. Research is consistent that integrating engineering practices and engineering design on the learning of science potentially makes learning meaningful, exciting and relevant. Recent research however is focusing on pedagogical integration of engineering into other STEM subjects. There is need to appraise the conventional/traditional methods of teaching chemistry usually adopted in various secondary schools in Nigeria, the problem inherent in the method, suggest alternative approach that would produce an effective teaching-learning process that is learner-centered and impact in the learner the skills and the competence for national development and global competitiveness.

Focus of Study

For 21st century learners, incorporating technology into the classroom can facilitate teaching-learning process. By using technology, teachers can bring chemistry to life and students will be able to visualize abstract concepts and test new learned concepts (Kristen et al., 2017). However, lack of resources especially in mediocre schools poses a challenge to implementation of technology in classroom (Bilwani & Zehra, 2016). Using technology as a way for students to build skills in weak subject areas will make difficult times of learning fun and enjoyable, but most importantly it will help students to build the confidence they need to succeed (Kristen et al., 2017).There is serious need for paradigm shift from the traditional teacher-centered teaching pedagogue to an improved alternative that is learner-centered. This becomes very necessary in the Nigeria education system to meet up with the global competitiveness and future economic prospects that STEM educational approach offers.

STEM Education is an interdisciplinary approach to learning; where rigorous academic concepts are coupled with real world lessons as students apply STEM in the context that make connections among schools, community, work and the global enterprises enabling the development of STEM literacy as well as self-reliance skills, and with it, the ability to compete in the new economy (Tsupros & Hallinen, 2009). We now live in a world where; you can't understand Science without Technology, which couches most of its research and development in Engineering, which you can't create without an understanding of Mathematics (Mpofu, 2019). There is need to strengthen the adaptation of the approach to the educational sector in general and chemistry in particular, to meet the 21st century educational standard and achieve sustainable development goals.

Traditional Pedagogue in Chemistry Teaching

Teachers' dominance in the traditional way of teaching chemistry does not encourage active learning that could imbibe in learner the skills for onward application in later live. Traditional teaching method is teacher-centered and inductive in nature. According to Arends, 2009; Jacobsen, Eggen & Kauchak, 2008, teaching methods are divided into teacher-centered and student-centered. This is due to different theories of learning sequentially emerged (behaviourism, cognitivism and constructivism) in the literature of learning.

Each of the teaching method has its theoretical bases from one or two of the learning theories (Hassan & Ibrahim, 2018). Choice of appropriate teaching method is hinged on a number of factors. The ability of the teacher to recognize the appropriate teaching method, teacher mastery of content and use of relevant tool to facilitate teaching in a manner that brings about the desired learning behaviours in the learner makes a good teacher. The focal point of teaching should move from teacher-centered teaching approach to learner-centered approach.

Problems with the Traditional Teaching Method in Chemistry

Arrays of problems make the traditional/conventional method of teaching Chemistry ineffective. The problems include but not necessarily limited to the following in the Nigeria secondary school chemistry context;

- Teachers' dominance of the teaching-learning process
- Over-theorizing of the learning concepts
- Teaching chemistry as a separate entity from other science subjects without underscoring the interdisciplinary relationship it has with other science subjects and making a whole body of knowledge by integrating the different subjects together
- Partial/non-implementation of aspects of the chemistry curriculum that specify hands-on-processes and skill acquisition
- Incompetence of chemistry teachers to handle available science materials and modern teaching tools
- Inability of teacher to innovate and improvise unavailable teaching aids
- Lack of incentive for improvisation of relevant teaching aids to facilitate teaching
- Acute shortage of competent and professional chemistry teachers in secondary schools
- Wideness of content of the subject to be delivered
- Short contact time/duration for teaching chemistry on the timetable
- Infrastructural decay and obsolete science materials due to poor funding of education
- Low motivation of teacher to go extra miles to fill learning gaps inherent/ peculiar to a specific content, where appropriate, among others

STEM Approach as 21th Century Alternative for Teaching Chemistry

Presently, it is indisputable that Science, Technology, Engineering and Mathematics (STEM) are the strong drivers of competitive national economies. Thus throughout the world, nations are busy investing in STEM with the hope of grooming innovative minds to spearhead the development and sustainable growth of their economies (Mpofu, 2019). STEM Education is evolving as a technology and ICT driven approach in responses to the recent global advancement in technology. Implementing digital education for Science, Technology, Engineering and Mathematics (STEM) requires acquisition of digital skills. As part of the Catalyst Initiative to facilitate STEM teaching and learning, Organization for Economic Cooperation and Development (OECD) presented five innovative models of STEM teaching and learning (Karkkainen & Vincent-Lancrin, 2013), namely

- Educational gaming
- Online laboratories

- Collaboration through technology
- Real-time formative assessment
- Skill-based curriculum alignment

Each of the itemized innovative models has it peculiarities and advantages

- Educational gaming involves student's interaction with video games, simulations or virtual worlds based on imaginary or real worlds, also seen as highly interactive virtual environments (Raju et al, 2011; Aldrich 2009). A simple Google search of chemistry games will put students in a virtual world of molecules, molar masses, and complex equations (Kristen et al., 2017). On You Tube, educative video on chemistry can help students learn better during the free time, at their own individual learning pace. Educational gaming promotes

✓ Learning by doing
✓ Student learning
✓ Student engagement and motivation
✓ Students' thinking skills

Common educational games that can aid learning of chemistry include:

➢ Chemcaper
➢ HoloLAB Champions
➢ Tiny Bubbles
➢ Organic pop
➢ Org Chem Adventure
➢ Happy Atoms
➢ Bond Breaker 2

• Online laboratories, whether remote or virtual, are another promising innovation to enhance the teaching and learning of STEM at all levels of education (Karkkainen & Vincent-Lancrin, 2013). Students, who struggle with abstract concepts, greatly benefit from online simulation (Kristen et al., 2017).Virtual online laboratories allow students to simulate scientific experiments while remote ones allow students to use real laboratory equipment from a distance through the Internet (Jona et al., 2011; Tasiopoulou & Schwarzenbacher, 2011). Virtual labs are one of the most effective ways that chemistry teachers can use to engage their students for active learning purposes (Saavedram&Opfer, 2012). Virtual labs allow students to experience what it is like to experience a chemistry job in a stem field. Utilizing technology in the classroom, affords the once shorthanded chemistry students, with a virtual chemistry lab (Kristen et al., 2017). Though virtual chemistry cannot fully replace students skills built during lab, it does give the students a realistic idea of how labs work, with the application of newly learned chemistry concepts. (Potkonjak et al., 2016). Advantages of online laboratories initiative includes

✓ Low-cost access
✓ Flexible access
✓ Student learning

QUIZ: How do you help students to acquire the skill to measure the EMF of a cell?

APPROACH: Pedagogue (by animation & simulator)

Cite this Simulator: amrita.olabs.edu.in,. (2013)

QUIZ: How do you close the learning gaps in teaching the following concepts in electrolysis?

- It is difficult to observe the solvation of ions in the dissolution of the ionic compound in water, because ions are in sub-microscopic and invisible form.
- It is also difficult to see ions moving randomly when added to water

Approach

- PhET simulation of ions moving randomly when added to water should be used to explain the dissolution of ions and the randomness in the movement of ions

Online laboratory simulations and animation are available on the site (amrita.olabs.edu.in,. 2013) for senior secondary chemistry for classes 9-12, in the different topics, For instance Class 9

TOPICS	Site for Online laboratory simulation
Separation of Mixture using different techniques	amrita.olabs.edu.in,. (2012). Separation of Mixtures Using Different Techniques. amrita.olabs.edu.in/?sub=73&brch2&sim=96&cnt=1
Chemical-Reactions	amrita.olabs.edu.in,. (2011). Chemical Reactions. amrita.olabs.edu.in/?sub=73&brch2&sim=77&cnt=1
Distinguishing between mixture and compound	amrita.olabs.edu.in,. (2011). Distinguish Between Mixture and Compound. amrita.olabs.edu.in/?sub=73&brch2&sim=70&cnt=1
Separation of Components of a Mixture	amrita.olabs.edu.in,. (2011). Separation of Components of a Mixture. amrita.olabs.edu.in/?sub=73&brch2&sim=39&cnt=1
Distinguishing between solutions	amrita.olabs.edu.in,. (2011). Distinguish Between Solutions. amrita.olabs.edu.in/?sub=73&brch2&sim=28&cnt=68
Melting point of Ice	amrita.olabs.edu.in,. (2011). Melting Point of Ice. amrita.olabs.edu.in/?sub=73&brch2&sim=30&cnt=1
Boiling point of Water	amrita.olabs.edu.in,. (2011). Boiling Point of Water. amrita.olabs.edu.in/?sub=73&brch2&sim=29&cnt=1
Rutherford's Scattering Experiment.	cdac.olabs.edu.in,. (2012). Rutherford's Scattering Experiment. cdac.olabs.edu.in/?sub=75&brch=12&sim=88&cnt=1
Exothermic and Endothermic Reactions	cdac.olabs.edu.in,. (2012). Exothermic and Endothermic Reactions. cdac.olabs.edu.in/?sub=75&brch=12&sim=92&cnt=1
Modern Periodic Table	cdac.olabs.edu.in,. (2012). Modern Periodic Table. Retrieved 23 cdac.olabs.edu.in/?sub=75&brch=12&sim=94&cnt=1
The Law of Conservation of Mass in a Chemical Reaction	amrita.olabs.edu.in,. (2013). The Law of Conservation of Mass in a Chemical Reaction. amrita.olabs.edu.in/?sub=73&brch2&sim=118&cnt=1

- Collaboration through technology can improve students' awareness of global challenges and develop their understanding of other cultures (Karkkainen& Vincent-Lancrin, 2013). The following can be achieved in STEM education using collaboration through technology.

✓ Flexibility
✓ Cultural diversity
✓ Student learning
✓ Student interaction and engagement
✓ Students' thinking skills

- Real-time formative assessment can be achieved by the use of clickers, tablet computers and other kinds of technology. This enables instantaneous interaction and

feedback between teachers and students (Karkkainen & Vincent-Lancrin, 2013). The innovation comes in two parts; with the real-time interaction targeting the learning of students, while the instantaneous feedback guiding the teacher on the next instruction to give. Both the teacher and learner are expected to have the resources and the skill to adopt this innovation to teaching- learning process. This educational innovation can help achieve the following:

✓ Targeted instruction
✓ Student learning
✓ Problem solving and creativity

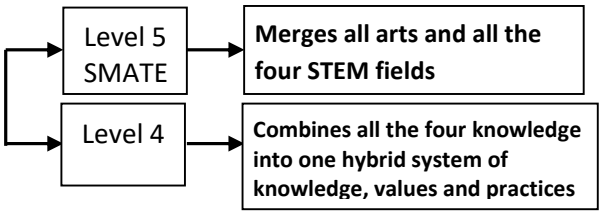
• Skill-based curriculum alignment could transform teaching from knowledge-based learning framework to skills-based learning as achieved in EcoleCentrale de Lyon, France. Skilled-based curriculum that is technologically driven can help promote more accurate assessment of the variety of skills included in STEM+ curricula and standard (Karkkainen & Vincent-Lancrin, 2013). While it is becoming increasing common to develop these kinds of skills-based curricula, their eventual impact on actual teaching and learning depend also on the availability of adequately aligned support systems (Ananiadou & Claro, 2009; Looney, 2011; Karkkainen, 2012). Technology can help measure complex skills such as reasoning or problem-solving through measures such as essays, blogs or virtual learning environments (Looney, 2009; Looney, 2011b; Ramirez-Corona et al., 2013).

✓ Adequate assessment

Theoretical Framework Required for Implementation of STEM Education

STEM education is usually misconceived among the teachers who should implement the curriculum owning to different STEM approaches adopted based on the context in which it is been used. In most nations, educators lack a cohesive understanding of STEM education and are deprived of an easy-to-understand STEM education framework that informs classroom practices. In this regard, STEM classrooms require teachers who hold knowledge and pedagogies associated with different STEM disciplines and who would be able to construct new identities within their nation and school contexts (Furner & Kumar, 2007; Pimthong & Wiliams, 2018).

The STEM model framework below can be easily adapted



Source: Adapted from STEME model = (Mpofu., 2019).

Challenges with the implementation of STEM in Nigeria

STEM has become unattractive among Nigerian students despite its many potential as a result of some challenges like:

➢ Support technology required is out-sourced. To promote innovation and support effective technology transfer in developed or developing countries unique competences, which are mainly available in research universities, high tech companies, and technology hubs are required (Gillet et al., 2019).

➢ It implementation as the 21st century teaching method requires acquisition of digital skills for both the teacher and the learner

- Dearth and poor quality of teachers is one of the factors hindering implementation of the approach in Nigeria.
- Poor infrastructure discourages implementation of STEM. STEM subjects, especially science and technology, have high demands in terms of resources including computers and laboratory equipment, consumable materials such as chemicals and textbooks. This puts a strain on the system which may already be struggling to provide a basic infrastructure, textbooks, which are considered critical in all STEM subjects, are often of poor quality and in short supply (Barrett, et al., 2019). For a nation to have a robust, goal getting and sustainable STEM Education, there must be good financial commitment to education in terms of funding
- Too much emphasis on certificates with less emphasis on skills and competence does not motivate learners to acquire skills; instead they focus on their grade.
- The belief that STEM is difficult and complex to adapt to classroom teaching piss off some teachers and students alike.

Conclusion and Recommendation

STEM Education has prospect to achieve substantial success in exploiting the potentials of Nigeria citizens to facilitate sustainable development by unleashing the untapped latent ability in the people. Classroom practices emanating from pedagogical STEM integration should be able to meet the criteria for an effective STEM instruction. Students in a pedagogic STEM integration classroom should be able to: (1) Solve problems, (2) innovate, (3) invent (4) logical think (5) self-rely and (6) technological literacy (Morrison, 2006). Policy formulation that would lead to good implementation and development of STEM literacy as well as self-reliance skills, and with it, the ability to compete in the new economy should be encouraged.

To meet up with the global competitiveness and future economic prospects that STEM educational approach offers, there is need for synergy between the policy makers and all stakeholders to achieve a functional education system for national development through implementation of a skills-based curricula. Less emphasis should be laid on certificates with more emphasis on skills and competence to meet the expectations of the labour market for human capital. It is equally important that the gown and the town collaborate that the educational institutions may produce the right workforce for industries with requisite skill and knowledge to drive economy, right from even basic classes. Teachers are nation builder, so the quality of the teacher determines to a large extent the quality of the nation. Teachers must be well equipped, skillful and motivated to implement the curriculum to achieve good result. To build human capacity for successful and sustainable implementation of technology driven STEM curriculum, personnel could be trained abroad to gain direct experience to be plough back to our education system or some teachers should be drawn from diaspora to lend helping hand in training indigenous teachers. Science fairs and workshops should be organized to polish the teaching methodology of teachers in-service.

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