



## Using ICT for Contemporary/Transformational Science Teaching

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### Abstract

The purpose of this paper was to explore conceptually the use of ICT for contemporary/transformational science teaching. This new or emerging paradigm for science teaching has been put in a perspective that reflects the rationale and context of this paper. It is argued here that ICT usage is the heart of this paradigm. The problems of integration of ICT into science teaching have been highlighted while the strands of evidence of the problems and the reviews generally have been converged to constitute a new research agenda.

**Key words:** ICT; Contemporary science teaching; Transformational science teaching; Constructivism; Problem solving.

### Introduction

An example of advances in technology is the Mars exploration which has raised the hope that humanity will soon become a multiplanet species. This example shows the stage of development of technology in some advanced economies. But Nigeria and other developing countries are still loitering on the crossroad to this development. From the foregoing, this paper is written with great deal of trepidation. It is not heart-warming that ICT is not massively employed for teaching and learning of science and technology at the various levels of our educational system. But we should start from somewhere. To that extent, it is gratifying that there are attempts to address ICT and science teaching.

It is heart-warming too to note that the Federal Executive Council (Nigeria) approved the National Information Technology Development Agency (NITDA) which was established in April, 2001 by the Federal Government to implement the National IT Policy and to promote the healthy growth and development of the IT industry in Nigeria. According to the then Honourable Minister of Science and Technology, Professor Turner T. Isoun, the vision statement of the Policy is “to make Nigeria an IT capable country in Africa and a key player in the Information Society by the year 2005, using IT as the engine for sustainable development and global competitiveness” while the mission statement is to “USE IT” for:

- i) Education
- ii) Creation of Wealth
- iii) Poverty Alleviation
- iv) Job Creation
- v) Global Competitiveness (Isoun, 2003 p. 3).

He acknowledges that a major strategy of achieving both the vision and mission of the IT Policy is Human Capacity Building which involves both Education and Training. He laments the scarcity of qualified human capital at all levels and attributes lack of sustainable growth and development of developing nations to this.

The Federal Government, through the National Space Research and Development Agency, pursued this bid for being an IT capable country in Africa vigorously. In September 26, 2003, in Plestek, Russia, the Federal Government launched the first satellite, NigSat- 1 into the orbit. According to Akinboade (2011) NigSat- 1 is one of the five disaster monitoring satellites that form a network called the Disaster Monitoring Constellation and by this will share information with one another when disaster monitoring is needed. Another communication satellite, Nigconsat, was launched in May, 2007 but got lost due to a cut in fuel supply link of the panel. Two others were launched in 2011 in Russia - NigSat- 2 and NigSat- x. The latter was built by Nigerian Engineers.

The question that arose from some Nigerians then was about the value these various launches would add to national development. Akinboade (2011) says that the satellites can be used for



demography like: mapping and planning of population survey; census enumeration areas; mapping, planning and monitoring of rural and urban growth; advance warnings of natural disasters like floods, earthquakes, volcanic eruptions and storms; managing oil pollutions; desertification, erosion, forest fire and deforestation; agriculture; land use geological mapping; and transportation. It is reported in *Telecoms, Internet and Broadcast in Africa, Issue No. 241*, that Nigerian satellite, NigSat- 1, has been actively involved in the mitigation of recent Asian Tsunami disaster, by supplying satellite images of the affected areas to aid agencies managing the disaster. This is progress, though it has no foundation. There is a vacuum somewhere.

The vacuum is located in the school system. This is the major source of the trepidation observed in this paper. Who are the scientists and engineers to replace those specifically trained in Surrey, UK and other places for this Satellite Project? Something serious must be done to bring about effective teaching and learning of science at all levels of education. ICT in science classrooms and laboratories, when effectively used, can bring about meaningful learning of science. This paper is therefore an open invitation to stakeholders, especially science teacher educators, and educatees educational administrators and supervisor, ICT entrepreneurs, and indeed all, to participate in deliberations on how to effectively bring in ICT into science classrooms and laboratories for effective teaching and learning of science. You are all encouraged to brainstorm and make some recommendations, using relevant materials to be presented, about ICT in science classrooms.

The purpose of this paper is to make a plea for the use of contemporary or transformational teaching approach which integrates ICT for science teaching. We shall conceptualise contemporary science teaching and discuss some aspects of ICT for contemporary science teaching. From the elaborations from the discussion we shall consider a new research agenda that highlights some challenges ahead for brainstorming and research.

## 2. Contemporary Science Teaching

It is auspicious at this point, to present the nature of science we are deliberating on. This is largely because science can mean different things to different individuals. The science education literature is replete with consensus that students and teachers understandings of the nature of science is central to achieving scientific literacy and meaningful learning of science (McDonald, 2008; Fittel, 2010; Igwebuike, 2013a). Bencze and Hodson (1999) identified seven misconceptions about scientific concepts from different school science curriculum documents. They are:

- i) observation provides direct and reliable access to secure knowledge;
- ii) science starts with observation;
- iii) science proceeds through induction;
- iv) experiments are decisive;
- v) science comprises discrete, generic processes;
- vi) scientific inquiry is a simple, algorithmic procedures; and
- vii) science is a value-free activity.

These misconceptions by science curriculum developers and teachers have implications for the use of ICT for meaningful learning in science. These will be highlighted later in this discussion. But it is necessary to say, at this point, that many of the students' alternative conceptions which are at dissonance with scientific conceptions (see Igwebuike, 1991a, 2013b, c) and which some scholars in science education inadvertently refer to as misconceptions (see Stein, Barman & Larrabee, 2007, McDonald, 2008; and Fittel, 2010) take origin from science and laboratory classrooms (Stein, Barman & Larrabee, 2007; Igwebuike, 2013a, b). Use of ICT for science teaching in contemporary classrooms and laboratories will provide myriads of learning experiences that will facilitate assessment, by the students, of the plausibility, intelligibility and fruitfulness of their alternative conceptions vis-à-vis the scientific conception of study (Strike & Posner, 1985). This assessment should be subtly managed to motivate the learner and respect his feelings (Pintrich, Marx & Boyle, 1993; Zhou, 2010; Igwebuike & Oriafio, 2012; Igwebuike, 2013a).



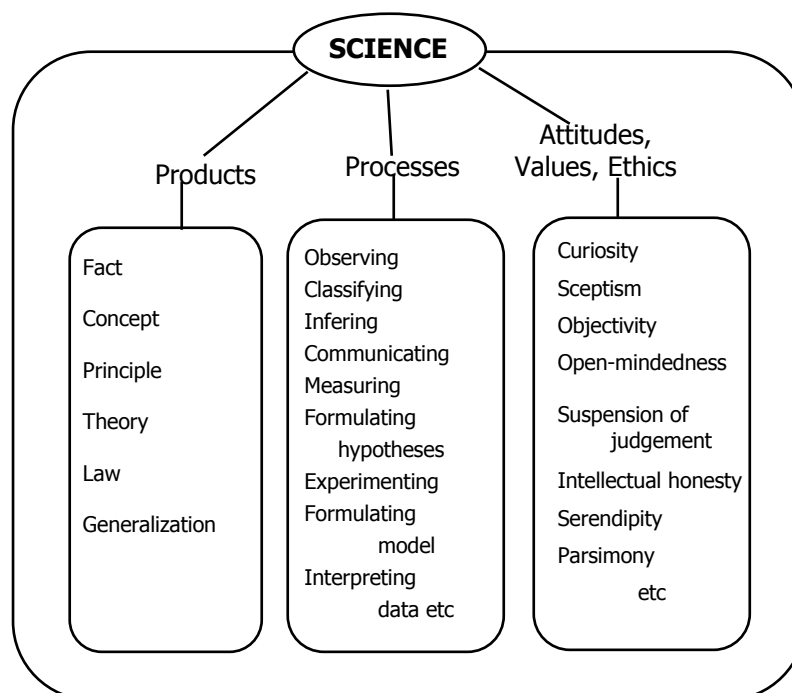
A summary of nature of science with seven aspects that are interrelated is provided by Bell, Lederman, and Abd-El-Khalick (2000) as, scientific knowledge is (a) tentative, (b) subjective, (c) empirically based, (d) socially embedded, and (e) dependent on human imagination and creativity. In addition, it distinguishes between (f) observation and inference, and (g) theories and laws. These can be concretized by different elementary biology students who make different sketches of the same *Amoeba* slide they viewed under a microscope. It is possible some of them will sketch anything they see since part of the theory is that *Amoeba* is amorphous and undergoes gel-sol-gel transformations. McDonald (2008) reviewed literature on nature of science and come up with nine aspects that represent consensus among science education scholars. They are:

1. Scientific knowledge is empirically based and generally derived from observations of natural phenomena.
2. Scientific knowledge is subject to change and cannot be considered absolute, although generally considered reliable or durable.
3. Science is not characterized by a universal scientific method
4. Scientific theories and laws are different types of knowledge and serve different roles in science.
5. Scientific knowledge is subjective and theory – laden and recognizes a student's background.
6. Observations and inferences are different concepts in science.
7. There is a creative and imaginative aspect to scientific knowledge; a major undertaking by scientists involves creating hypotheses, inferences and theories.
8. Scientific knowledge is socially and culturally embedded.
9. Moral and ethical issues influence decisions reached by scientists.

Teaching Science for Meaningful learning implies that these various aspects of nature of science should be integrated.

Nature of science can also be appreciated by considering its triadic structure. It is a composite of products, processes and attitudes and values.

The structure is given in fig. 1 below:



**Fig. 1: Triadic Structure of Science**



Products of science are: fact (observations), concepts, principles, theories, laws and generalizations. These constitute the corpus of scientific knowledge that is found in science curriculum. It is also referred to as curricular science by Gilbert and Zylbersztajn (1985) which they describe as a modification of the scientists' science. Processes of science are ways scientists develop scientific knowledge. They include: observing classifying, inferring, predicting, measuring, communicating, interpreting data, raising questions, formulating hypotheses, making operational definitions, experimenting and formulating models. Presentation of processes here does not reflect any form of ordering. For instance, making operational definition can come in before observation is made since definition may either depend on the operation to be done or on observable characteristics of the object, event, or phenomenon under investigation (Igwebuike; 1983).

Scientific attitudes and values include objectivity, skepticism, open-mindedness, curiosity, parsimony, suspension of judgement until there is ample evidence, intellectual honesty, serendipity. Attitudes are in the affective realm, and by implication students should be adequately motivated during science teaching to develop scientific attitudes through the use of processes of science.

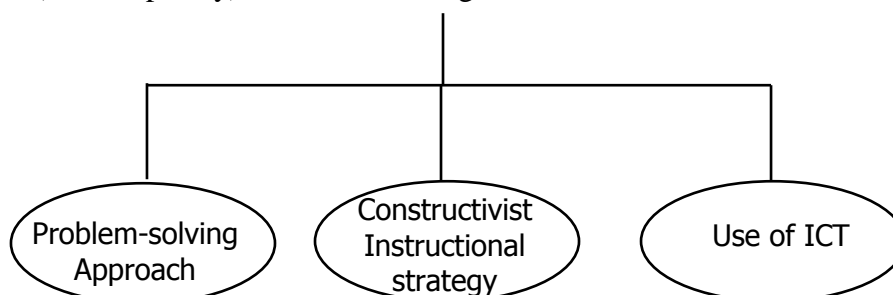
Contemporary science teaching should be based on the nature of science which has been described by exposing the various aspects of it and the triadic structure of science. From the foregoing it is patently difficult to use processes of science to develop scientific knowledge and attitudes in the students without using ICT effectively. Contemporary science teaching is effective science teaching and can also be referred to as transformational science teaching as against transactional science teaching. It may be necessary to consider this dichotomy.

## 2.2 Transformational Vs Transactional Science Teaching

The status quo in science teaching at the various levels of education is patently transactional. In transactional science teaching, science teachers and lecturers simply prepare their lesson or lecture notes strictly from the curricular science. They transfer the subject matter from their notes to the students' notes without creating learning opportunities that can make the subject matter cross the minds of the students and their minds too. Students receive measures of the subject matter like acolytes – unquestioningly. It involves the transmission of knowledge from the teacher/lecturer to the students. Students are expected to assimilate and synthesize the knowledge. If and when practical work is involved, students simply confirm results and observations of scientists (from scientists' science) using practical/laboratory manuals where applicable. At times, there is alternative to practicals even at the university level. This approach to science is indeed a damning indictment of transactional science curricula which are in use in the institutions.

Transformational science teaching emphasizes student-centred approach to teaching. It aims at developing critical thinking, inquiry skills, good communication skills, curiosity and openmindedness in the student. Learning environment is organized for the students to assess the limitations of their conceptions and skills. They are assisted and guided to make a shift to the new skills and conceptions. Scientific conceptions of study must be linked to the larger community of the students. Transformational science teaching can be embarked upon through the use of some strategies like problem-solving approach, constructivist instructional strategy, use of ICT etc.

Transformational (Contemporary) Science Teaching



**Fig. 2: Strategies for transformational science teaching**



### 2.2.1 Problem-solving Approach

This is also known as heuristic teaching approach which according to Urevbu (1990) and Igwebuike (2011) assists the learner to develop initiative, critical thinking, analysis, self-reliance, good judgment, and manipulative skills by being personally involved in problem-solving activities during science lessons. The learners will develop these skills and more because they are placed in the active role of real life practitioners. This type of learning environment provides interaction among learners to gather information/data required for solving the social problem raised within the subject matter of study. The joy that will result from solving the problem will form the substratum for epistemic and intrinsic motivation (Igwebuike, 2013a) for solving other problems. From the foregoing, problem-solving approach is both learner and community centred. Specifically, the steps involve in this approach are:

1. Formulation of a problem;
2. The search for information or data that will assist to solve the problem;
3. Determination of the procedure to use;
4. Executing the procedure (e.g. collection of data/information; and
5. Interpretation of the data/information or discussing the implications.

Once a suitable problem has been chosen, it becomes necessary to engage and excite the students through the use of simulations, videos, newspapers or popular magazine articles, dramatization. Other aspects of ICT can be employed for solving the problem, as will be elucidated later.

Many real-life problems can be solved using this approach. Igwebuike (2011) gives examples of such problems in the area of social studies as: overpopulation in the urban areas, corruption in the society, HIV/AIDS; cultism, youth restiveness; flooding; desertification; food security; community life, and social intelligence etc. A lot more can be included, for example, marriage of a minor girl-child. Some of these problems can be addressed in the area of science and more can be identified.

### 2.2.2 Constructivist Instructional Strategy

Constructivist instructional strategy (CIS) is based on constructivist epistemology which acknowledges that a learner actively generates meanings from experience and develops his personal constructs or minitheories or what we have already referred to as alternative conceptions. The learner can show a tenacious hold of these personal conceptions (Igwebuike, 2013d in press) especially if the science classroom/laboratory does not provide challenging activities for him to test the plausibility, intelligibility, and fruitfulness (Strike & Posner, 1985) of his conceptions. But the major purpose of the CIS is not to force the learner to drop his alternative conception but to help him to develop the habit of challenging one idea with another and appropriate skill for 'having alternative conceptions compete with one another for acceptance' (Hewson, 1992). Views of learning sponsored by constructivist epistemology, according to Driver and Oldham (1986), are:

1. Individuals are Purposive - learning does not take place by the learner responding in a passive way to the environment.
2. Prior knowledge matters a lot – learning depends not on the learning environment per se, but on what knowledge the learner brings to the learner situation.
3. Knowledge is constructed by individuals through social interactions and experience with physical environment, personal knowledge is constructed so as to 'fit' with experiences in a coherent way.
4. Meaningful learning involves the construction of links with prior knowledge.
5. The construction of meaning is an active process in which the learner generates possible hypothetical links and checks them for 'fit' in the situation.
6. Learning involves conceptual change; it involves not only adding and extending one's conceptual structure but may involve radically reorganizing it.

Meaningful learning, as can be seen from these views of learning, can take place when the learner's alternative conceptions are explored and used during instruction. The conceptions are tested for Strike and Posner's (1985) criteria within instructional events typified by the sequence below:



1. Determine students' alternative conceptions using different methods (see Igwebuike, 2000; 2013d)
2. Catalogue the alternative conceptions according to types;
3. Determine the conflict or dissonance level (see Igwebuike, 1991b);
4. Carefully present the subject matter of study;
5. Carry out conflict resolution through negotiation which will lead to consensus building (Jegade & Taylor, 1998);
6. Assess, with the students, the usefulness, fruitfulness and intelligibility of the students' alternative conceptions vis-à-vis the subject matter of study;
7. Discuss the application and implication of the knowledge developed; and
8. Determine the students' affective state after they have discarded their dissonant alternative conceptions.

Efficacy of CIS has been endorsed by several strands of research evidence (Rowell & Dawson, 1985; Trumper, 1990, 1991; Asim, 1999; Bajah & Asim, 2000; Igwebuike, 2000; 2013b, c; Igwebuike & Oriafio, 2012, 2013; Ndioho, 2007). It is heart-warming to observe that this example of transformational teaching approach has produced desired effects and this is why Cey (2011), Taber (2006), Fittell (2010), and Karagiorgi and Symeou (2005) have recommended its use for science teaching. Karagiorgi and Symeou (2005) in particular, strongly suggest that accommodating constructivist perspective by instructional designers can help them respond to the learning requirements of the 21st century. All these endorsements are tutored by the efficacy of ICT, for instance in providing concept mapping heuristics and interview-about-instances cards (Igwebuike, 2011), among others, for probing students' alternative conceptions.

### 2.2.3 Uses of ICT

From our descriptions of transformational science teaching, it is clear that use of ICT is imperative. It is very crucial and not just tangential because, among others, according to Olusanjo (2007), it will make teachers and teacher educators to change their roles from mere content experts or task masters and assessors to those of modeling and facilitating collaboration and enquiry. At this point, it is auspicious to elaborate on the role of ICT in transformational science teaching. This is the heart or the overarching issue in this paper.

### 2.2.4 Summary of Characteristics of Transformational Science Teaching

A summary of the characteristics of transformational science teaching can be seen from Slavich (2005) as follows:

- i. The teacher is conceptualized as an instructor of the relevant material and also change agent who guides students through the transformational process.
- ii. In his or her role as change agent, the teacher works to decrease students' perceived barriers to success while increasing their self-efficacy for change.
- iii. Teaching centres on the use of self-change projects but requires previous mastery of the course concepts through teaching methods.
- iv. Students are viewed as being capable of mastering the course content and achieving the target changes (p. 5 – 6).

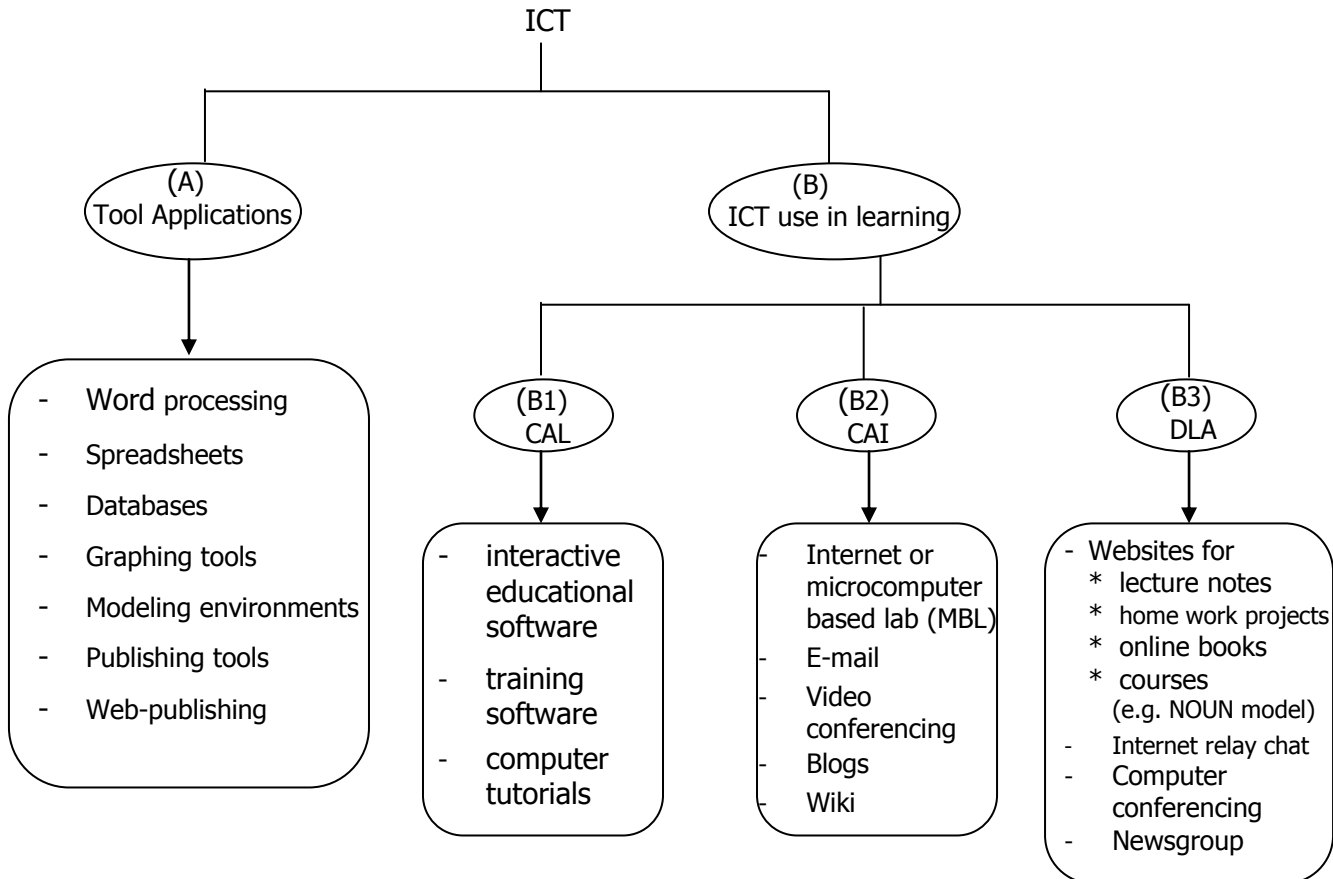
## 3. ICT for Transformational Science Teaching

3.1 It may be necessary to define ICT in the context of this presentation to provide a common conceptual canvas. Osborne (2003) sees ICT as computer-based tools and resources. Lavonen (2008) endorses this approach to the conceptualization of ICT when he refers to use of computers in education as use of ICT in education. He goes on to classify ICT in science education as follows: (a) Tool applications (use of tool software) and (b) ICT in learning (learning through ICT). 'Within the tool category' A, ICT reflects a set of softwares which facilitate effective accomplishment of tasks by the



students. The use of word processing and spreadsheet for learning of science belongs to this category. Other tools in this category include: databases, graphing tools, and modeling environments.

This classification of uses of ICT indicates that ICT in learning (B) has three categories: (B1) computer-assisted learning (CAL); (B2) Computer-assisted inquiry (CAI); (B3) Distance learning approach (DLA). A sketch of this classification is attempted below:



**Fig. 3: Classification of ICT in science education**

ICT use in learning (B) involves as has been mentioned, computer-assisted learning (CAL), Computer-assisted inquiry (CAI) and Distance learning approach (DLA). CAL provides interactive interface between a student and a computer system prepared to facilitate learning. It incorporates tutorials, drills, games and simulations and virtual-reality environments. These can be used for developing scientific knowledge as well as scientific skills and attitudes in the student. Even in Nigeria, as in other developing countries, computers and computer based products are fast becoming a reality of our environment.

CAI involves using ICT to facilitate collection of data from various sources. Inquiry by students generally follows these steps: formulating a question, designing an investigation, gathering data and evidence, formulating an answer and communicating the procedure and results. It is investigative in nature and to that extent it agrees with the nature of science and contemporary science teaching in general. It is synonymous with development of interest and sound scientific reasoning as is required by the scientific attitude we have earlier referred to as suspension of judgment (until ample evidence is obtained through inquiry). McDonald (2008), as we have seen earlier, says that part of the consensus on nature of science by science education scholars is that scientific knowledge is empirically based and generally derived from observations of natural phenomena. This is an endorsement of the use of CAI. In addition CAI reflects the way a science teacher should organize science/laboratory environment for transformational science teaching.



DLA includes e-mail and mailing lists which Lavonen (2008) says are the most popular Computer Mediated Communication (CMC) tools for exchanging messages between individuals. These and other related forms like video conferencing, newsgroups can create learning situations that require social interactions. Peer group members can learn science by working together within CMC learning situations. Students can have contacts, through this means, with experts and community resource persons. Computer conferencing enables groups of people to hold discussions by reading and posting text messages on a computer system. Internet Relay Chats (IRC), according to Lavonen (2008), allows users to chat 'live' using text or audio. Web-Based Learning (WBL) is also an essential part of DLA. Items like lecture notes, homework assignments, online books, courses, etc can now be located on the Web. This has led to the creation Web-Based Learning Environments (WBLE). This is endorsed by DeVaney, Adams and Elliott (2008) when they say that online education for post-secondary instruction is a rapidly expanding enterprise among public and private universities. They successfully designed and validated an instrument – Online Constructivist Learning Environment Survey (OCLES '20') for assessing the quality of that type of learning environment.

From the foregoing, if effectively used, ICT can bring about transformational science teaching. This can be further buttressed by at least three characteristics of ICT. The first is that provides tools for making science teaching to be learner-centred because it is the learner that interacts with those tools. The second is that its use is consistent with the reality in our environment. The third is that its use facilitates problem-solving approach to science teaching and learning. Skills of problem solving are related to social skills to the extent that they assist the individual to gather evidence upon which judgment about an issue can be predicated. Let us at this point consider other justifications for the use of ICT for transformational science teaching though Igwebuike (2011) observed that usefulness of ICT is no longer controverted and that scholars in ICT area have gone beyond establishing the rationale for ICT in education.

### 3.2 Justification for the Use of ICT for Transformational Science Teaching

Several scholars of ICT use in teaching and learning have suggested different aspects of ICT that facilitate or potentiate effective learning in science. The table below shows such aspects and their uses.

**Table 1: Aspects of ICT and their uses**

S/N.	Types	Uses
i.	Simulations and modeling (Owen, 2003; Sengel, Ozden & Geban, 2002; Azar & Sengulec, 2011; Adegoke & Chukwunenye 2013)	Help students to understand scientific phenomena that may be slow (e.g. germination of seed), too fast, dangerous or expensive to carry out and for investigating the cause-effect relationships.
ii.	Databases and spreadsheets (School of Education, Leicester Univ., 2003)	Assists students in searching and sorting out information to explore relationships and test hypotheses.
iii.	Publishing and presentation softwares (School of Education, Leicester Univ. 2003)	For students to develop understanding of concepts and for communicating the findings of their investigations to others
iv.	Information resources e.g. internet, CD Rom and data files (Denby, 2002)	For sourcing information that will help them develop scientific knowledge and understanding.
v.	Data logging, use of sensors to record changes in variables like temperature, light intensity, pressure, moisture etc (Denby, 2002; School of Education Leicester Univ. 2003)	Can assist students in recording, communicating and analyzing results so as to have more time for interpreting results and drawing implications of the results
vi.	ICT generally (a) (Ajagun, 2003)	For facilitating acquisition of higher- order thinking skills and problem-solving skills





vii.	<p>b. School of Education, Leicester Univ. (2003)</p> <p>c. Olusanjo (2007)</p> <p>Use of course blogs to publish/assignment and students creating common Wiki as a product of a task or project towards learning networks (Rudd, Sutch &amp; Facer, 2006; Lavonen, 2008; Lacina &amp; Griffith, 2013)</p>	<p>For helping student to raise questions, predict, hypothesize, observe, measure, record and manipulate variables, interpret results and evaluate scientific evidence, present and communicate their results in different ways.</p> <p>For assisting the student to become self-directed inquirer capable of defining their goals of learning and monitoring their own progress rather than awaiting instructions on tasks.</p> <p>For assisting students foster the spirit of cooperative learning through learning networks (virtual communities) and to develop problem-solving skills further.</p>
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The potentials of the use of ICT can also be found in the presentations by Osborne and Hennessy (2003), Wellington (2003), Jimba and Ishaleku (2003), Akubuilo and Ndubuizu (2003), Denby and Campbell (2005). But it is considered necessary to present a distillate of potentials of the use of ICT for science teaching by Lavonen (2008) who says it can:

- make learning active, constructive, contextual, co-operative, self-regulated, reflective, and cumulative and engage students in tackling the topic to be learnt in such a way that they create meaningful and understandable knowledge structures on the basis of a goal of learning;
- increase interest, motivation and engagement in activities;
- provide access to resources (web pages, texts, databases, videos, demonstrations, applets) that are of high quality and relevant to scientific learning;
- help students to focus attention on overarching issues, increasing salience of underlying abstract concepts;
- enable visualization and manipulation of complex models, three-dimensional images and movement to enhance understanding of scientific ideas;
- support exploration and experimentation by providing immediate visual feedback;
- help students to learn to use ICT or increase their digital competence; and
- expedite and enhance work production and offering release from laborious manual processes and more time for thinking, discussion and interpretation;
- increase currency and scope of relevant phenomena by linking school science to contemporary science and providing access to experiences not otherwise feasible (pp. 23 – 24).

It is gratifying as well as heart-warming to observe that these various benefits derivable from the use of ICT for teaching science are in consonance with the triadic structure of science which must be emphasized while teaching science for meaningful learning. They all indicate that teaching and learning of science should reflect an intricate dovetail of products and processes of science and scientific attitudes and values. The use of ICT also makes teaching of science to be learner-centred and in addition it provides a classroom/laboratory environment for problem-solving and for probing and challenging students' alternative conceptions. To that extent use of ICT is endorsed for transformational science teaching which has been amply and aptly described earlier in this paper. This means that ICT can be used for intervention, during science teaching, on the time-honoured saga of students underachievement which many scholars in science education (Eniayeji, 1986; Okebukola, 1986; Oriaifo, 2000; Igwebuike & Oriaifo, 2012; Ogunkola, 2012) have raised trepidation about. What this means is that with time, Nigeria will produce scientists and engineers that will participate in global competition in the use of science and technology and join in space exploration etc.



But we should not be cajoled by the scholarly presentations of the benefits of the use of ICT into thinking that all we have to do is to provide the schools with some good measures of ICT and all these benefits will automatically manifest. There are other intervening factors which must be addressed. Prominent among these is the teacher organizing the classroom/laboratory environment for the use of ICT. Many questions can be raised about the teacher. For instance, what is the nature of pre-service teacher education programme that trained him professionally? What is his conception of teaching and learning? What is his attitude towards using ICT for teaching science? What is his self-efficacy belief about the use of ICT for teaching science? What about his professional development through in-service education? What about his job satisfaction level and his welfare generally? What is his workload?

Answers to some of these questions are not heart-warming. For instance, a study by Igwebuike, Okandeji and Ekwevugbe (2013) revealed that teacher educators in colleges of education in Delta State have traditionalist/transmissive conception of teaching and learning instead of contemporary/constructivist conception, Traditionalist/transmissive conceptions of teaching endorses transactional teaching approach. Most teachers teach the way they were taught (Igwebuike & Okandeji, 2013). In the final analysis, teacher education institutions can be implicated in the use of transactional approach which negates contemporary/transformational science teaching. Some studies (Andoh, 2012; Bukaliya & Mubika, 2012; Owolabi, Oyewole & Oke, 2013) have indicated that teachers do not have the desired level of positive attitude towards the use of ICT for teaching and learning. But a study by Onyegebu (2003) indicated that 68.02 per cent of science teachers investigated had positive attitude towards the use of ICT for teaching. Despite the fact that teachers claimed that they were aware of the benefits of the use of ICT (Ayeni & Ogunbameru, 2013), it has not influenced teaching and learning processes in the secondary schools in Nigeria (Okoro, 2008; Olulube & Ubogu, 2009; Ugwoke, 2011) because of lack of institutional support in the provision of adequate infrastructural facilities like electricity, internet services, bandwidth, maintenance of ICT facilities (Okoro, 2008; Yusuf & Onasanya, 2004; Adeyemo, 2010). This can be implicated in the observed lack of self-efficacy belief in the use of ICT by teachers (Ando, 2012; Mingaine, 2013).

### **Integrating ICT into Teaching Methods**

Teaching method can be considered as statement(s) which provides a rationale for the interaction patterns between a teacher and his students, and among the students during a lesson. It indicates the psychosocial interactions that define the nature of classroom learning environment. But teaching is a polymorphous activity which can take many forms and activities (Hirst, 1975), and teaching science is a very complex activity (Igwebuike & Oghenesuvwe, 2013; Lavonen, 2008). By implication, it is foolhardiness to structure out or prescribe a model for integrating ICT into teaching method that is suitable for all types of classroom interactions. The way the integration can be carried out depends on the context and content of the lesson. It also depends on the learners' needs, interest, dispositions, ability level and nature of alternative conceptions with reference to the level of conflict with the scientific conception. It also depends on the teacher's attitudes towards the use of ICT for instruction, his competence and knowledge of the subject matter. Be that as it may, integration of ICT must involve the student who should be assisted to develop a self-directed and self-motivated approach to the study of scientific phenomenon under investigation. It should also emphasize learning cooperatively and collaboratively in small groups while carrying out practical activities.

### **Reasons for Under-utilization of ICT for Science Teaching**

Apart from the teacher factor on which we raised and addressed some questions, there are other factors that hinder utilization of ICT for science teaching. They are:

- i) **Lack of Institutional/government support in providing infrastructures for ICT at the various levels of education:** The recommended percentage of a country's annual budget for education by UNESCO is 26. But in Nigeria the ear-marked percentage is scarcely above unit and the eye-marked value is left for the reader to imagine. Patently, there is serious paucity of fund for education. But the cost of providing ICT infrastructure, including hardware and software and the research



involved is reasonably high. Another aspect of infrastructure is electricity supply which is limited and unreliable. Another devastating problem is corruption. There is poor management of ICT projects which leads to ineffectual use and unnecessary duplication sometimes or most times lack of the ICT components.

ii) **Student-related Factors:** In the urban areas of Nigeria, many of the students at the secondary level and most of them at the tertiary level have personal mobile phones. Many are already using social media for communication, and even some in the rural areas have mobile phones. Apart from the fact that acquisition of social media varies among the students, there is skills gap among teachers and lecturers for converting the content of communication in social media to scientific conceptions, attitudes and values, and process skills. This conversion is expected to assist the students to develop self-regulated and self-motivated approach to the study of scientific phenomena.

iii) **Unweildy/ambitious Curriculum Packages:** Many of the curriculum packages are over bloated with corpus of scientific knowledge. This is one of the problems of transactional curriculum which has been discussed earlier. Teachers are often transmitting scientific knowledge to their students with the sole aim of completing their scheme of work or course outline. Teachers with this frame of mind or persuasion will find it difficult to search for ways of integrating ICT into their lessons.

iv) **Gender:** Gender has been implicated in the issue of under-utilization of ICT for teaching (Mingaine, 2013). The implementation of ICT in schools in Kenya, Jimoyiannis and Komis (2007) observe, has given rise to new social stereotypes and gender inequalities. This is because ICT-related activities are perceived as masculine. They are supported by Olagunju (2003), Andoh (2010) and Makhanu (2010). Strands of evidence from these and other related studies converge to indicate that female teachers and students have less positive attitudes towards the use of ICT as well as lower level of competence for its use.

v) **Teaching Experience and Age:** Another factor that influences utilization of ICT for teaching is teaching experience. Associated with this factor is age. There is controversy on the influence of teaching experience. For instance, while Andoh (2012), and Lau and Sim (2008) found in their studies that use of ICT is positively correlated with teaching experience, Laaria (2013) found that teachers with less teaching experience were more likely to use ICT in teaching than their more experienced counterparts. In addition, Khan, Hasan and Clement (2012) observed that experienced teachers are less inclined to use ICT for teaching. But the debate can be concluded by referring to the observation by Khan, et al (2012), that there exists a perception that the newly employed teachers are more likely to be more experienced with ICT and more committed to its use than teachers with experience. It appears more plausible to accept this considering the fact that such 'new teachers' had recent encounters with ICT in their teacher education programmes. In the case of age, Himoyiannis and Komis (2007) concluded in their study that older teachers are less likely to use ICT for teaching than the younger ones. Their conclusion appears plausible.

#### 4.0 Challenges Ahead and New Research Agenda

Challenges of global competitiveness in science and technology compel every country of the world to seriously revamp the teaching of science and technology. Nigeria's Vision 20 – 2020 will be a mirage if science teaching does not reflect transformational precepts. This paper has sharpened our conceptions of transformational science teaching and exposed how ICT can help to achieve this model of science teaching. A number of challenges precipitate in the process of integrating ICT to science teaching as can be seen from discussion on reasons for underutilization of ICT.

Challenges that are teacher-related can be handled, among others, by professional development of the science teacher through both pre- and in-service teacher education programmes. Mingaine (2013) suggests specifically that courses for in-service professional development of the science teacher should focus on:



- Skills and applications of ICT
- Integration of ICT into existing curricula
- Changes in the curriculum and in ICT use
- Teacher roles in implementation of ICT
- Management of ICT in schools
- Legal and ethical issues of ICT in schools
- Educational and learning theories (p. 125).

What is lacking in this outline is the attitudinal and motivational aspect of the use of ICT in teaching. Teachers attitudes and motivation for using ICT should be seriously considered so as to generate the required level of interest which is the greatest motivational factor in teaching and learning. These items above can also be used as conceptual canvas among others, for revamping science teacher education programme in various institutions.

Preparation of students for the use of ICT for learning is another major challenge. Acknowledgably, many of the students are already using smart phones and some other social media for communication. But many more students, especially those in the rural areas, cannot afford these media because of acute poverty in the land.

Budget for education in Nigeria which is much lower than UNESCO recommendation, as well as provision of infrastructural requirements like power, etc constitute, another challenge. This is a task for politicians but they should be sensitized on the need to improve drastically the budgetary provisions for education. This challenge justifies the labour dispute currently going on between ASU, COEASU and ASUP on the one side and Federal and State governments on the other. In specific terms, lack of total commitment on the part of government towards the development of ICT sector for educational purposes and inadequate funding of internet connectivity because it is capital intensive (Owolabi, Oyewole & Oke, 2013) should be addressed.

#### 4.1 A New Research Agenda

From the foregoing, some items can be generated for developing new research agenda as follows:

- Determining how to integrate ICT into the teaching of different science subjects;
- Investigating professional needs of science teachers for using ICT for teaching science;
- Investigating gender differential in the use of ICT for science teaching and indeed, the influence of other teacher variables on its use;
- Investigating science teacher self-efficacy belief in the use of ICT;
- Determining the various ways ICT can be used for teaching science in a way that reflects its triadic structure – products, processes and scientific attitudes and values;
- Investigating how science educators, teachers and ICT specialists can synergize or potentiate one another to create ICT programmes that are science content specific;
- Determining the efficacy of the use of ICT for transformational science teaching at the primary and secondary school levels;
- Finding out how to make students at the various levels to be self-directed and self-motivated in the use of ICT, that is how to assist students develop self-regulated learning.
- Investigating the use of ICT within various techniques-concept maps, mind maps, interview-about-instances (IAI), interview-about-events (IAE), demonstrate, observe and explain (DOE), word association/generative proposition (WA/GP), etc for probing students' alternative conceptions in science;
- Probing ways of exposing the interface between scientific literacy and social media and determining how to consolidate the relationship between the two.
- Investigating how to use ICT for knowledge management during conflict resolution phase (negotiation) in which students test the usefulness and validity of their alternative conceptions.
- Embarking on studies on how to facilitate faculty renewal in the area of use of ICT for science teaching.



- Sourcing for data and information needed for revamping science teacher education programme at all levels.
- Determining how blogs or weblogs can be improved for developing blogging or virtual communities for problems solving in science and for publishing assignments etc.
- Carrying out studies about digital literacy – its methodology, evaluation, and implementation.

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