The Implications of ICT and NKS for Science Teaching: Whither Nigeria

Francisca Aladejana*
Institute of Education,
Faculty of Education,
Obafemi Awolowo University,
Ile-Ife, Nigeria

In Nigeria, science teaching at the various levels still retains the old conservative approach and if this situation would change, there is the need for a diagnostic study. This paper examines the attitude to the use of information and communication technologies (ICT) and *A New Kind of Science* (NKS) for learning science among undergraduates from selected universities in Nigeria. It determines the impact of the use of simple computer experiments on the learning of science and also assesses the availability of resources for this new paradigm. Multiple research methods were used including questionnaire, observation, discussion, and interview. The students' attitudes were measured using an adapted established instrument, which was administered on 50 undergraduates purposively selected based on having any basic science as their subject of specialization. Analysis was done using descriptive and inferential statistics.

Findings from the study reveal that the attitude of most of the students to using ICT and NKS for learning science is good and receptive. The use of ICT and NKS for teaching and learning science were said to make learning more meaningful and encourages active student participation. There is very poor availability of resources, and a low level of confidence in handling computers for this type of learning. Based on these findings, appropriate recommendations are made for improving science teaching and learning in Nigeria using ICT and NKS.

1. Introduction

Globally, the use of information and communication technologies (ICT) is fast gaining prominence and becoming one of the most important elements defining the basic competencies of students. According to World Bank [1], ICT consists of the hardware, software, networks, and media for the collection, storage, processing, transmission, and presentation of information. The use of ICT falls into four major categories: constructing knowledge and problem solving (through the Internet, email, CD-ROMs, databases, video-conferencing); using process skills; aiding

*Electronic mail addresses: faladeja@oauife.edu.ng, faladeja@yahoo.com.

explanation of concepts; and communicating ideas (powerpoint, desktop publishing) (WCEA, 2002).

The use of ICT in teaching is a relevant and functional way of providing education to learners that will assist in imbibing in them the required capacity for the world of work. Very few jobs today do not require the use of skills in technology, collaboration, teamwork, and information; all of these can be acquired through teaching with ICT. It fundamentally changes the way we live, learn, and work.

Various research has identified the importance of ICT in education. It has been found that ICT can promote students' intellectual qualities through higher order thinking, problem solving, improved communication skills, and deep understanding of the learning tool and the concepts to be taught [2]. ICT can promote a supportive, interactive teaching and learning environment, create broader learning communities, and provide learning tools for students, including those with special needs [3, 4]. Computer-generated graphics have been used to illustrate relationships of all kinds, especially dynamic processes that cannot be illustrated by individual pictures [5]. They are also said to improve school attendance levels and enable the creation of a new and more effective curriculum.

According to [1], ICT in education initiatives are most likely to successfully contribute to the Millennium Development Goals of increasing access through distance learning, enabling a knowledge network for students, meeting teacher training targets, increasing the availability of quality materials, and enhancing the quality of administrative activities. Other identified ICT uses for learning include that it removes age, distance, and time constraints from any learning process and provides effective library services [6]; makes for interactive learning, using a learner centered and activity oriented teaching approach [3, 7]; energizes the students [4]; encourages deeper understanding about data collection, saves time on measuring and recording, and helps in analysis [8].

Stephen Wolfram's *A New Kind of Science* (NKS) is a novel use of ICT, specifically its use of computers in learning and explaining concepts. According to [9], NKS is a very new concept consisting of over 800 programs covering a huge range of computational functions and concepts. The programs are extremely short and clear, making use of the many programming paradigms available in *Mathematica*®. In NKS, Wolfram discusses the connections and implications of his discoveries for a wide range of issues in mathematics, physics, biology, and computer science. He also uses mathematics as a crucial tool with applications to both existing and new methods of analysis.

Wolfram uses his approach to tackle a remarkable array of fundamental problems in science from the origins of apparent randomness in physical systems, to the development of complexity in biology, the ultimate scope and limitations of mathematics, and the possibility of a truly fundamental theory of physics. Thus, NKS has introduced a new paradigm for doing science, which is now developing not only in science but also in technology, business, and the arts.

According to [10], NKS involves changing paradigms from the computational sciences to the science of computation. According to [11] the NKS book is a positive heuristic with key ideas for generating new models and problem solutions, predictions or explanation of novel facts, or novel explanation of existing known results. Its inventory of current successes is in solving existing problems or predicting, describing, or explaining existing natural phenomena. Some previous studies have shown that NKS can be put to use in various fields including: [12] on reversible cellular automata, [13] on the use of cellular automata models in ecology, and [14] on the multi-set programming paradigm. With NKS, many if not all natural processes can be thought of as computations driven by very simple algorithms, like biological growth patterns.

This information about NKS has thrilled me as a biology teacher of over 25 years at both the secondary and tertiary levels of education and has inspired in me a deep sense of inquisitiveness to learn more about NKS and possibly find a way to bring it to the attention of my colleagues and also students that are being trained as teachers.

Teaching approaches should change from teacher-based instruction to learner-based learning where teachers facilitate learning, and this can be largely achieved with ICT and NKS. In order to achieve this, teachers do not only need formal training in ICT and NKS use, but also sustained and ongoing training to help them integrate technology into their teaching. According to [15], teachers must have access to professional development programs to enable them to master skills for the use of ICT in classrooms.

2. ICT use in Nigeria

Presently in Nigeria, science teaching at the various levels still retains the old conservative approach with the teacher, in most cases, acting as the repertoire of knowledge and the students the dominant recipient. There is an over-reliance on textbooks and only occasional demonstrations and experimental classes. In an average classroom, one finds a teacher at the blackboard jotting down important facts, students furiously copying all that is written and said, expecting to memorize the facts and spit them out on an examination. According to [1, 4], the majority of teachers in African, Latin American, and poor countries generally not only lack adequate hardware and software, but also reliable Internet access. These are significant barriers to using computers in instruction, government, and business.

With the increased momentum of technological revolution sweeping across the world, there is the need for teaching and learning in Nigeria to change such that the computer is brought into the classroom and a diagnostic study is needed to help move in this direction. With globalization and the world a global village, a bridge is required across the digital divide in the teaching/learning process between the technologically rich developed countries and the technologically poor developing countries like Nigeria.

3. Objectives

The specific objectives of the study are therefore to:

1. assess the availability of resources for computer-assisted teaching and learning
2. identify other problems of ICT use for teaching and learning
3. examine the attitude to ICT and NKS use for learning science among Nigerian undergraduates
4. determine the impact of the use of simple computer experiments and programs on the learning of science.

4. Theoretical framework

The study is predicated on the assumption that the use of computers affects the motivation of students in the learning and enjoyment of science and mathematics and that appropriate use of software packages can enrich, support, and mediate the learning of science and mathematics concepts. The study is underpinned by the theory of constructivism, a philosophy which perceives learning as a process of adjusting mental models to accommodate new experiences: constructing knowledge, developing thinking skills, building learners' ability to reflect, and generating strategies for defining a problem and working out solutions rather than working on answers that a teacher wants. Thus, learning how to learn, knowing how to know, and contextualizations of learning are some of the features of constructivism [16, 17].

5. Methodology

This study uses qualitative data collected using a variety of sources. Multiple research methods were used including questionnaire, notes based on observation, discussion, and interview comments. Two questionnaires were used in collecting data. First a 10-item questionnaire ARCAL, with a reliability coefficient of 0.81, was designed to assess the availability of resources for computer-assisted learning. ARCAL was administered on 106 purposively selected science teachers from

25 schools chosen by stratified random selection using the criterion of government or private ownership.

The second questionnaire has 20 items and was adapted from an established and validated instrument, the Selwyn-Soh Information Technology Attitude Scale (SSITAS). It is a five scale Likert type instrument developed to assess five subscales of attitudes toward ICT use. According to [18], here are the five main subscales.

1. *Affective component*: deals with the generalized emotional reaction to a computer and its use, that is, computer anxiety. This assesses whether the user may have fear, apprehension, discomfort, or hesitation with regards to ICT.

2. *Perceived usefulness factor*: denotes the perception that computer enhances work performance. This assesses whether the user finds a computer to be generally helpful, productive, imaginative, and interesting in relation their work.

3. *Perceived behavior component*: assesses the habitual behavior with regards to computers and whether a computer is used regularly.

4. *Perceived control component*: assesses a person's perceived ability to control the computer and also gives an indication on the level of confidence in handling and using the computer.

5. *Defense component*: assesses a person's defensive attitude against the use of ICT.

There were four questions for each of the five subscales. Ten of the 20 questions had positive scoring of strongly agree = 4, agree = 3, disagree = 2, strongly disagree = 1, and not sure = 0. The remaining ten had reverse scoring such that strongly disagree = 4 and strongly agree = 1. SSITAS has been validated in Nigeria by Jegede in [19] who got a reliability coefficient of 0.90. It was administered on 50 purposively selected Obafemi Awolowo University, Ile-Ife undergraduates based on the criterion of having any basic science as their area of specialization. The total score for each of the undergraduates were then calculated and analyzed using descriptive statistics. According to [19] the rating of attitude can be described thus:

Score	Rating
0–20	Very poor
21–40	Poor
41–60	Good
61–80	Very good

Data were gathered using semi-structured interviews conducted with 20 of the science teachers. These teachers were asked to comment on their use of technology in teaching, and the problems they have with using ICT. Also, observations were carried out in the classes of ten randomly selected science teachers from both secondary schools and universities. The study was to determine the impact of using simple computer experiments and programs on the learning of science and to assess the facilities available and/or used. The teachers were not given prior notice of the observation to ensure that reality was observed. After each observation, discussions were held with the teachers.

6. Results

An assessment of the ways in which teachers use ICT in teaching indicated that none of the secondary schools used ICT in any of the following ways: talking books, spread books, database software, television with teletext, video-recording of lectures, power presentation, and video-conferencing. Only 9.43% asked students to browse for information on the Internet, 2.83% have used overhead projectors, and 1.89% made use of CD-ROMs containing educational topics. None of the teachers have heard about NKS, what it means and involves, and its possible relevance to their science teaching. These findings are indications that the teachers virtually do not involve the use of ICT and NKS in their science teaching. This agrees with the earlier findings of [1, 4, 19].

The results showed that 20.0% (5 out of 25) of the schools have one or two computers which children have access to and only 4.0% (1 out of 25) have more than two computers for children's use. None of the schools have a laptop, LCD projector, video-recorder, talking books, sensors, database software, spreadsheet, or floor robots. Only one school (4.00%) has an overhead projector. Individuals, organizations, or religious bodies privately own all five schools that have computers and learners pay exorbitant fees to attend them. None of the public secondary schools have computers and/or Internet access. Children attending such schools with ICT facilities are mainly from a high socio-economic class. This can be a major source of digital divide among learners. These classrooms can therefore be described as technologically poor where teachers virtually do not use ICT in the classroom.

Six out of the 106 teachers (5.67%) have personal computers, which they said were used mainly for business/commercial purposes rather than for teaching. The Internet connection of the only school that has access is by fixed line infrastructure (wires). None of the institutions have the broader band wireless connection or even dial-up connectivity using telephone lines. However, teachers said some of their students have computers at home and a few have Internet access outside the classroom. It can thus be said that the classrooms are still very much traditional without much influence of ICT and NKS.

Other problems in the use of ICT for teaching and learning identified from the study include the following:

- Unreliable Internet access in the school that has connectivity because the server is often down.

- Lack of electricity. Seven out of 25 schools (28%) have electricity supplied to restricted areas like the principal's office, reception, and staff rooms but not in any of the classrooms. Only six schools (24%) have electricity in all parts of the school including the classrooms.

- Epileptic supply of electricity. The situation is such that 14 out of the 18 schools that have electricity (77.77%) have power failures for two or more days in a row. Most teachers said they cannot rely on the current state of the electricity supply to plan any lesson activity. They said they cannot afford generators and fuel to supply the required electricity. Only one out of the 25 schools, a privately owned school, has a functioning generator.

- Large class size. Class size is said to be very large, especially in the public schools. In the 25 schools studied, none of the schools had a class size below 30, six (24%) had class sizes between 30 and 39, ten (40%) had class sizes between 40 and 60, while nine (36%) had class sizes above 60. In this type of situation, even where computers are available, the computer to student ratio is terribly low and alarming.

- Lack of adequate funding. The results showed that 81 out of 106 teachers (76.42%) said a major obstacle to the use of ICT for teaching and learning is lack of funds. In all the schools, teachers said the government does not provide funds for this purpose. Computers and other ICT facilities are not supplied to the schools. Teachers at the few schools that have some ICT facilities said they are mostly funded by the Parents Teachers Association (PTA) of the school.

- Lack of technical experts in schools who can deal with maintenance issues and resolve problems such as viruses and other technical problems. 9% of the teachers said such technical ICT experts are not likely to remain in the school system where salary is relatively poor compared to what they can earn in business ventures, banks, and engineering companies.

- Government policy. 46 out of 106 teachers (43.40%) said the fact that there is no section in the Nigerian National Policy on Education specifically requiring teachers to carry out computer assisted learning does not make it mandatory for school proprietors (state or private) to provide the required ICT facilities. Many stakeholders in the school organization do not therefore see this as a priority for execution. In 20 out of 25 schools (80%), there are no well-secured, appropriate room spaces to keep computers as they are in high demand and prone to burglary.

  All the teachers said that the Nigerian National Curriculum for primary and secondary science, the official document of the Federal Ministry of Education used compulsorily by all schools and which stipulates the activities to be carried out by the teachers, does not include any ICT integrated activity and that teachers tend to limit themselves to the stipulated activities.

- Lack of professional training in ICT integrated teaching. 22 out of the 25 teachers (88%) lack the required skills in technology to become confident and creative in the use of ICT for teaching. They have never had any training on the integration of technology into their teaching. 8 out of 25 (32%) do not even see the rationale for integrating ICT into learning in a country like Nigeria where there are other more pressing human needs to be met. These teachers would rather prefer their present teaching styles to technology-oriented teaching.

  18 out of the 25 (72%) teachers cannot access the Internet; 16 out of 25 (64%) cannot even start up and shut down a computer safely. These groups of teachers definitely cannot use software, or word-process any document. They obviously will not be able to obtain information from the Internet for any educational purpose.

These identified problems are herculean and do not seem to have the required and desired government intervention and commitment to funding by other stakeholders in education (e.g., NGOs, industrial sectors) and the parents.

The findings show that 40% of the respondents are afraid to use a computer because of damaging it, 30% would rather avoid work that involves a computer, 18% agreed that they are not in control when using a computer, 24% are apprehensive about using a computer, 32% would only use a computer when it is absolutely necessary, 28% avoid coming into contact with computers in their work, 36% hesitate to use a computer for fear of making mistakes, and 34% said computers make them feel uncomfortable.

However, 54% said using a computer does not scare them at all and that they use one regularly for their work, 44% said they do not feel apprehensive about using it. These students gave advantages derived from using a computer to include: help in organizing work better (66%), enhance work (74%), allows one to do more interesting and imaginative work (56%), and makes it possible to work more productively (72%).

A summary of the analysis for attitude to computer use showed that for the affective component, 12% of the respondents have a very poor emotional reaction to computer use, 42% poor, while the remaining 46% have a good to very good rating (Figure 1). This is an indication that most of the students have anxiety and fear about computer use. With regards to the perceived usefulness factor, only 10% rated very poor and 18% poor in terms of assessing how helpful, productive, and imaginative computer use can be, the remaining 32% agreed that a computer can enhance their work performance. Thus, most of these students perceive that computers can enhance their work performance. Analysis of the students' perceived behavior indicated that 66% rated poor and very poor with respect to use while only 34% use a computer fairly regularly. In spite of the fact that many of the students are aware of the usefulness of computers, many are still not using them.

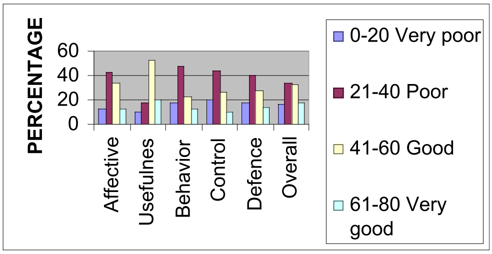

Figure 1. Attitude rating.

	Attitude Subscales: Rating							
Range of Scores	0–20: Very Poor		21–40: Poor		41–60: Good		61–80: Very Good	
	#	%	#	%	#	%	#	%
Affective Component	6	12.00	21	42.00	17	34.00	6	12.00
Perceived Usefulness Factor	5	10.00	9	18.00	26	52.00	10	20.00
Perceived Behavior Component	9	18.00	24	48.00	11	22.00	6	12.00
Perceived Control Component	10	20.00	22	44.00	13	26.00	5	10.00
Defense Component	9	18.00	20	40.00	14	28.00	7	14.00
Overall Score	8	16.00	17	34.00	16	32.00	9	18.00

Table 1. Analysis of responses on attitude subscales using SSITAS.

The results showed that the perceived control component is poor/very poor for 64% of the students, indicating that only 36% of the students can control a computer and handle it with some level of confidence. Most of the students rated poor in the defense component as 58% of them are apt to defend themselves against using a computer. On the whole, the overall rating indicated that 16% of the students have a very poor attitude to computer use, 34% have a poor attitude, 32% have a good attitude, while 18% have a very good attitude (Table 1). Thus about half of the students have a good attitude to computer use. A good proportion of the students can therefore be said to have a good attitude to using a computer. This is quite encouraging in the sense that this gives hope for the future use of computers in the classroom. If the resources are available, if the teachers are trained and favorably disposed, then one does not envisage much trouble in getting the students to use computers in learning.

Observations of the classes of the science teachers revealed that none of the secondary school teachers used any computer experiment or program. In the university, only two out of ten teachers (20%) were found using a computer program for teaching. These two were found in the Faculty of Technology. Interviews with their students revealed that they enjoyed the classes better, could work more productively, found learning interesting and imaginative, and are used to working on a computer without getting scared. The classrooms can thus be described as technologically poor as the computer is virtually nonexistent in them.

7. Recommendations

1. Government should make concerted efforts to provide the required ICT facilities for secondary schools. Budgetary allocations should be made specifically for this purpose. There is the need for drastic action to improve power supply in the nation.

2. There is the need for government policies to take care of issues such as class size, training of teachers in ICT for teaching, funding, provision of ICT facilities in schools by school proprietors (state or private), and the inclusion of ICT-integrated activities into the curriculum.

3. Professional training (both inservice and preservice) should be provided for teachers to equip them with the required skills for ICT-integrated teaching and learning.

4. Parents, NGOs, industrial sector, ICT producing companies, all employers of labor, and the international community must not leave the job of making schools ICT-integrated to the government, but rather all hands must be on deck to ensure the technological change.

5. Efforts must be made by the teachers to allay the fear and apprehensiveness of students to using a computer. They should be encouraged to feel comfortable in using computers and guide them to realize the advantage of such use.

References

[1] "How Do ICT in Education Initiatives Contribute to the Millennium Development Goals?" World Bank, (2006); www.worldbank.org/website/external/topics.

[2] B. B. Sutton, "Pedagogy and Curriculum," *Center for Media in Community*, EDC, (2006); www.digitaldivide.net/news/view.php?headlineID=701.

[3] S. Trinidad, J. MacNish, J. Aldridge, and B. Fraser, "Integrating ICT into the Learning Environment at Sevenoaks Senior College," Paper AlD 01027, (2001); www.aare.edu.au/01par/ald012027.htm.

[4] R. J. Hawkins, "Ten Lessons for ICT and Education in the Developing World," World Bank, (2002); www/cid.harvard.edu/cr/pdf/gitrr2002_ch04.pdf.

[5] H. W. Franke, "The New Visual Age: The Influence of Computer Graphics on Art and Society," *Leonardo*, **18**(2) (1985) 105–107; www.dom.org/essays/frank01.htm.

[6] B. Adekomi, "The Challenge of an ICT-Driven Instructional System in an Era of Aching Economy," *Faculty of Education Seminar Paper*, Obafemi Awolowo University, Ile-Ife, Nigeria, 2006.

[7] J. Carter, "A Framework for the Development of Multimedia Systems for use in Engineering Education," *Computers and Education*, **39** (2002) 111–128.

[8] K. Bryant, J. Campbell, and D. Kerr, "Impact of Web Based Flexible Learning on Academic Performance in Information Systems Education," *Journal of Information Systems Education*, **14**(1) (2003) 41–50.

[9] S. Wolfram, "Book Summary," (2003); www.wolframscience.com/summary.

[10] K. Boquta, "Complexity and the Paradigm of Wolfram's *A New Kind of Science*," *Complexity*, **10**(4) (2004) 15–21.

[11] J. Kadvany, "Review of Stephen Wolfram's *A New Kind of Science*," (2002); www.math.usf.edu/~eclark/Kadvany_Review_ANKS.html.

[12] R. Alonso-Sanz, "Reversible Cellular Automata with Memory: Two-dimensional Patterns from a Single Seed," *Physica D: Nonlinear Phenomena*, **175**(1–2) (2003) 1–30.

[13] J. Molofsky and J. D. Bever, "A New Kind of Ecology," *Bioscience*, **54**(5) (2004) 440–447.

[14] E. V. Krishnamurthy, V. K. Murthy, and V. Krishnormurthy, "Biologically Inspired Rule-based Multiset Programming Paradigm for Soft-computing," *Proceedings of the First Conference on Computing Frontiers*, edited by Stamatis Vassiliadis, Jean-Luc Gaudiot, and Vincenzo Piuri (Ischia, Italy, April 14–16, 2004).

[15] C. Godfrey, "Computers in Schools: Changing Pedagogies," *Australian Educational Computing*, **16**(2) (2001) 14–17.

[16] T. M. Duffy and D. J. Cunningham, "Constructivim: Implications for the Design and Delivery of Instruction," in *Handbook of Research for Educational Communications and Technology*, edited by D. H. Jonassen (Macmillan Library Reference, New York, 1996).

[17] "Funderstanding," *Constructivism*, (2001); www.funderstanding.com.constructivism.cfm.

[18] K. C. Soh, "Cultural Validity of Selwyn's Computer Attitude Scale," submitted to *Computer and Education*, 1998.

[19] P. O. Jegede, "A Study of the Predictors of Teacher Educators' Behaviour towards ICT in Southwestern Nigeria," unpublished Ph.D. Thesis submitted to the Department of Special Education and Curriculum Studies, Obafemi Awolowo University, Ile-Ife, Nigeria, 2005.

[20] J. Leach, "Do ICTs Enhance Teaching and Learning in South Africa and Egypt?" (2005); www.digitalopportunity.org/article/view125462/1/1072.