International Journal of Education and Development using Information and Communication Technology (IJEDICT), 2009, Vol. 5, Issue 2, pp. 88-104

Development and validation of a computer instructional package on electrochemistry for secondary schools in Nigeria.

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ABSTRACT

The computer has witnessed a wide range of applications in virtually all human endeavours. It has also found its way into the classroom, and educators now look in its way as a panacea to prevalent pedagogical challenges. Researches have indicated that appropriate use of the computer for science instruction facilitates teaching and learning. This research work was carried out to develop and validate a computer instructional package on electrochemistry for secondary schools in Nigeria. Several researches have indicated electrochemistry to be one of the topics responsible for students' poor performance in School Certificate Chemistry examinations in Nigeria. The package was produced in an html format using Macromedia Dreamweaver as the overall platform. Other computer programs utilized during the development process are: CorelDraw suit 12, Microsoft Word 2003, Macromedia Fireworks 8, and Macromedia Flash 8. The validation of the package was carried out in accordance with the recommendations of Dick, Carey, & Carey (2005). In the end, the package was found to produce a very good performance level in the students when used for electrochemistry instruction.

Keywords: *Computer; ICT; electrochemistry; ECIP; Nigeria.*

INTRODUCTION

The use of computers has dominated human activities especially in the last two decades. Its use is complemented by a whole lot of other electronic devices, all of which are now collectively regarded as Information and Communication Technology (ICT). Consequently, the first item that comes to mind when ICT is mentioned is the computer. Simply defined, the computer is an electronic device used for storing, processing, and retrieving information at high speed and accuracy. The global adoption of the computer has been the landmark of the educational scene for the last two decades. The adoption of the computer into education has often been premised on the potential of this 'new' technological tool to revolutionalize an outmoded educational system and as such better prepare students and the average citizen for the information age, and or accelerate national development efforts (Albirini, 2006). According to Harvey (1983), the effectiveness of the use of the computer in education is an important factor in determining which countries will succeed in the future, and central to this vision is the powerful metaphor of the 'information age' where media, business and industry become increasingly computer-reliant.

The computer has not only witnessed a wide range of application in virtually all human endeavours, it has also actually transformed the world into a global village in such a manner that its contribution to human development over the years can not be overemphasized. The computer plays a central role in information data collection, processing and dissemination. It is so much involved in ICT such that its exclusion may give another meaning to the acronym 'ICT'. Thus, the use of the computer is invading the educational system in a way unparalleled in previous education history (Onasanya & Adegbija, 2007). However, the digital divide existing between Africa and other continents of the world is responsible for the low level of computer utilization in education in the continent. Jager and Lokman (1999) listed the general functions of the use of

ICT in education to include the use of ICT as a tool for organization and management in schools. Also, Ojo (2005) listed the potential benefits of ICT in Sub-Saharan Africa to include the use of ICT for educational purposes. Further still, Yusuf (2005) stated that ICT provides opportunities for schools to communicate with one another through e-mail, mailing lists, chat rooms while at the same time providing a quicker and easier access to more extensive and current information. Besides, it can also be used to do complex mathematical calculations. Yoshimura, Sagakami, Fujikami, and Newbold (1994) asserted that Computer Aided Instruction (CAI) when used to complement the conventional teaching method, would encourage chemistry teaching and learning. They concluded by stating that chemistry teaching should be advantageously innovated by the use of the computer in association with practical experiment. According to them, CAI can be used to run beforehand learning for practical experiments in chemistry, and it has been found to be educationally effective.

The Federal Government of Nigeria has initiated policies at ensuring that Nigeria is not left behind in the global drive towards the use of the computer in enhancing development. Efforts made so far by the government towards ICT development in Nigeria include the launching of the National Telecommunication Policy in September 2000, development of a comprehensive science and technology policy in 2001, the development and launching of the National IT policy in 2001, the establishment of the National Information Technology Development Agency (NITDA) in 2001, and the launching of the Nigeria satellite systems programme by the National Space Research and Development Agency (NASRDA) in 2001. Other efforts made are: the granting of license to mobile telephone network operators beginning with MTN in 2001, development of a ministerial initiative on e-education for the Nigerian education system by the Federal Ministry of Education in 2004, formulation and presentation of IT bill to the national assembly in 2006, and the organisation of computer training for teachers across the country by Educational Trust Fund (ETF) in 2006.

COMPUTERS AND ICT IN THE NIGERIAN EDUCATION SYSTEM

The Provision of an appropriate framework for the full integration of ICT into the education system of a developing nation such as Nigeria is the responsibility of the federal or central government as the case may be. In the year 2001, the Federal Government of Nigeria published the National Policy on Information Technology (IT), and established the National Information Technology Development Agency (NITDA) to serve as the umpire in the implementation of the policy. However, the document failed to adequately address the issue of the integration of ICT into the Nigerian education system. While the document presented the issue of ICT in education vaguely, other sectoral aspects of the society such as Governance, Health, Agriculture, Arts, Culture and tourism etc were given individual sectoral treatment. There was no sectoral treatment for education in the document. The document only merely mentioned issues relating to education under the sectoral application for ‘human resources development’. One would have expected education to be treated distinctively like the other sectors therein, so that there are clear cut policy statements to guide stakeholders. It is to be noted that the document does not give any emphasis on the development of indigenous software that are in tune with the educational needs of Nigerians, neither does it address issues of its incorporation into teacher training, classroom instruction and evaluation. The policy listed nine major strategies for realising the objectives of applying IT in human resources development, one of which is ‘making the use of IT mandatory at all levels of educational institutions through adequate financial provision for tools and resources’. While these noble strategies are applauded, the implication of the inadequacies in the document is that the National IT policy cannot adequately take care of the need of the Nigerian education system (Yusuf, 2005). Perhaps it would not be out of place to say that Nigeria is yet to actually have a national policy on the integrations of ICT into her education system'.

In the year 2004 however, the Federal Ministry of Education released a document termed 'the ministerial initiative on e-education for the Nigerian education system. This document was an approval in principle for e-education project for the Nigerian education system. It did not take the place of a national policy on ICT in education. The document listed the major objectives of e-education in Nigeria as follows:

1. To enhance access to quality education.
2. To improve the education delivery system.
3. To ensure optimal utilization of existing ICT resource.
4. To ensure a globally competitive education system, and
5. To reduce / eliminate social vices in the school system.

The document appraised e-education worldwide and made a case for the Nigerian education system to adopt e-education. It however rationalized the need for e-education while at the same time highlighting the strategies for its adoption. The strategies proposed are: policy enactment, capacity building, advocacy, and curriculum review. While reflecting on the Nigerian situation on e-education, the Federal Ministry of Education reported in the ministerial initiative on e-education that a pilot study conducted by the National University Commission (NUC) showed that the average number of computers per school increased between 1998 and 2001, and that it witnessed a greater increase between 2000 and 2004. So also it was reported that there was a considerable increase in the percentage of schools connected to the internet, and there was an increase in the percentage of teachers that feel confident on the use of the computer in 2003.

The Federal Ministry of Education and its agencies have initiated many ICT driven programmes. These programmes include the SchoolNet Nigeria, the National Open University of Nigeria (NOUN) and the Virtual Library project. The NUC is implementing a number of ICT projects including Library Automation project, Nigerian Universities Management Information System (NUMIS), Nigerian University Network, Virtual Institute for Higher Education Pedagogy (VIHEP), and the Virtual Institute for Higher Education in Africa (VIHEAF). NUC is also conducting an e-learning pilot programme for Nigerian universities. Nigerian universities have been encouraged by NUC to utilize at least twenty percent of their teaching and research equipment grant for ICT development.

Conferences, workshops, and seminars are being held across the country on the integration of the computer into the Nigerian education. The science Teachers Association of Nigeria's (STAN) annual conference held in Abuja in August 2003 had many stakeholders in attendance. Lecturers from higher institutions, ministry officials, teachers across the various levels of education, and students were in attendance. The conference also had attendance from overseas. This included delegates from the United States, the United Kingdom, Ghana, South Africa, and Botswana. A total of seventy six papers were listed in the proceedings of the conference for presentation, across the various panels. The papers presented reviewed the status of ICT in Nigeria as at 2003, and they provided suggestions and recommendations that could enhance ICT integration into the Nigerian education system. Particular emphasis was on the use of ICT in science education since the theme of the conference was 'Information and Communication Technology and Science, Mathematics and Technology Education'. Nigeria is benefiting from the One Laptop Per Child (OLPC) programme being championed by Professor Nicholas Negroponte. Two schools in Abuja i.e. Junior Secondary School, Jabi, Abuja and Local Authority Grammar School, Galadima, Abuja have already benefited from the programme since March 2007. In these schools, each class is made up of a maximum of forty students, each having his or her own laptop. According to a Federal Capital Universal Basic Education (UBE) official, fifteen more schools have also been packaged for the project in the 2008 UBE commission's budget (Nigerian Television Authority nationwide news, 24th of January 2008). In the same vein, The Nigerian Communication Commission (NCC) is providing 365 schools in Nigeria with ICT centres, each to be provided with 31 computers. The NCC chairman had already commissioned the first one at Oriwu model College, Ikorodu in Lagos (Nigerian Television Authority network news, 3rd of February 2008). At the moment, awareness about the potency of the use of ICT for enhancing teaching and learning continues to increase with schools at all levels of education now making ICT literacy as part of their requirements for recruiting teachers.

Research problem

The overall performance of Nigerian Secondary school students in their Senior School Certificate Examinations in chemistry over the years has not been encouraging. Several researches (Ahiakwo, 1984; Bojuwoye, 1985; Onwu & Moneme, 1986; Kenni, 2001) have been conducted to unravel the factors responsible for this persistent dismal performance. These studies have been conducted in search of ways of improving students' performances. Figure 1 shows the performances of WAEC candidates from the year 2000 to 2006.

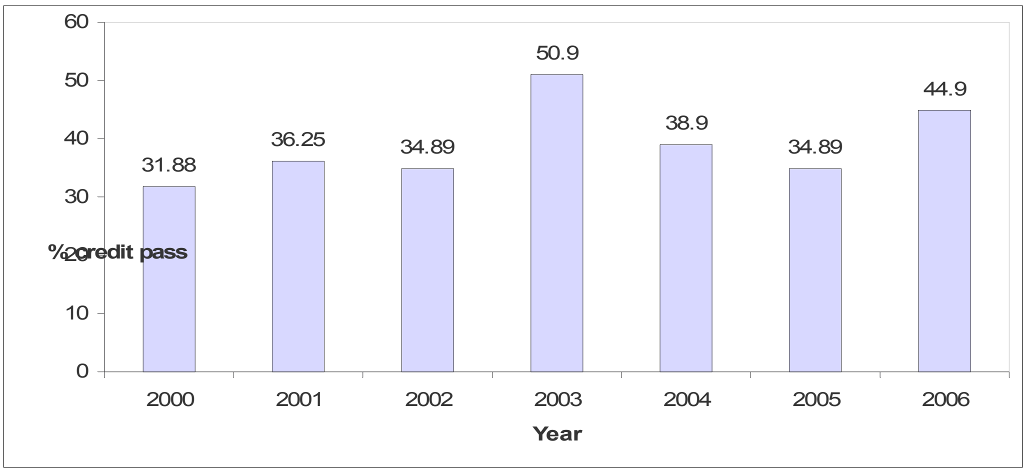

Figure 1: *Percentage credit pass of candidates in Chemistry (2000 to 2006) in the West African Senior Secondary School Certificate Examination* . ***{****Source: Research Division, West African Examinations Council (WAEC)} Lagos.*

A critical examination of this chart reveals that the highest performance in Chemistry was in the year 2003, when the percentage credit 1-6 was 50.9%. The lowest performance was in the year 2000, when the percentage credit 1-6 went down as low as 31.88%. For a country that is yearning for technological advancement, these figures are not encouraging. If we are to have better results, there is need to make frantic efforts at improving our pedagogical styles to enhance a better understanding of difficult Chemistry concepts. This is why this research looked in the way of the computer as a possible panacea to students' dismal performance in chemistry.

Electrochemistry is a topic in the curriculum of the Nigerian secondary school chemistry curriculum. According to Silberberg (2000), electrochemistry is the study of the relationship between chemical change and electrical work. Electrochemistry has been reported to be one of the topics that students find very difficult to understand in secondary school chemistry (Finley, Stewart & Yarroch, 1982; Onwu & Moneme, 1986; Okpala & Onocha, 1988; Garnett & Treagust, 1992; Thompson & Soyibo, 2002; Oyelekan, 2006). Onwu and Moneme (1986) tried to find out the extent to which some Nigerian chemistry students failed to solve electrolysis problems through the use, non-use or misuse of different stages of a problem solving model, the results confirmed that the students generally found solving problems in electrolysis difficult. In another study in Ibadan, Nigeria, four thousand three hundred and forty four students in grade eleven were studied by Okpala and Onocha (1988). The result of their study revealed that 50% of the students regarded electrolysis as one of the most difficult concepts to understand. More recently, Oyelekan (2006) carried out a study to find out the level of understanding of selected chemistry concepts by senior secondary school students in Osun state, Nigeria. Two hundred and ninety one senior secondary school III (SSIII) students from six purposively selected secondary schools were used for the study. The result of his study indicated electrochemistry to be one of the topics in which the level of students' understanding was very low.

There are ample evidences in the literature that establish the potency of the use of the computer in facilitating the teaching and learning of not only difficult concepts in chemistry but chemistry as a whole. For instance, researchers claim that computer-mediated instruction in comparison to the conventional methods of teaching can enhance the discovery environment (Reid, Zhang, & Chen, 2003), transform learners' alternative conceptions (Jimoyiannis & Komis, 2001) support a collaborative learning (Milrad, 2002), create technological processes (Michael, 2001), enhance understanding of scientific conceptions (Ronen & Eliahu, 2000), provide an interactive 3-dimensional visual stimuli environment (Sung & Ou, 2002), stimulate students' scientific problem solving skills (River & Vockell, 1987), and enhance students' conceptual change (Tao & Gunstone, 1999). According to Oloruntegbe and Odutuyi (2003), the often perceived difficult and abstract concepts in chemistry such as radioactivity, mole and stoichiometry, electrochemistry, organic chemistry etc. can be encoded or programmed into computer softwares that teachers and students could utilize to make their teaching and learning better.

Purpose of the study

The main purpose of the research was to transform the electrochemistry content of the Nigerian secondary school chemistry curriculum into a computer software, and then package it into a CD-ROM which could be used for teaching and learning of electrochemistry at that level. The package has been termed Electrochemistry Concept Instructional Package (ECIP). Validation of the software was done to ensure its suitability, and effectiveness in enhancing the teaching and students' learning of electrochemistry.
Specifically, this study sought to find out:

1. whether the subject matter content of the developed Electrochemistry Concept Instructional Package (ECIP) sufficiently covered the required areas of electrochemistry in appropriate and sequential manner.
2. whether the design and development of the ECIP conformed with acceptable standards of educational technology.
3. the performance level of students in electrochemistry when taught using the ECIP.

METHODOLOGY

Procedure for the development of the Electrochemistry Computer Instructional Package (ECIP).

This study is based on the theoretical foundations of instructional design as provided by the Dick et al. model (2005), and the social constructivist learning theory. Both approaches represent a range of diverse interests and methods but also general assumptions about learning designs (Richards, 2005). An important branch of cognitive psychology that impacts very much on the Dick et al. model which was adapted for this study is constructivism. According to the trio, constructivism has had a major impact on the thinking of many instructional designers. A central point in constructivism is that learning is always a unique product “constructed” as each individual learner combines new information with existing knowledge and experiences. Individuals have learned when they have constructed new interpretations of the social, cultural, physical and intellectual environments in which they live. A primary role of the teacher therefore is to create appropriate learning environments in which students’ learning experiences are authentic representations of real practices in applied settings (Dick et al. 2005). Bearing in mind the basic principles of constructivism, attempt has been made in this study to create appropriate learning experiences for the students through the ECIP that has been produced. In other words, the interactive property of the ECIP, coupled with the simulations provided in it were aimed at providing learning experiences that would enhance memory retention and improve students’ performance in chemistry examinations.

The electrochemistry content of the Nigerian secondary school chemistry, as specified by the Nigerian secondary school chemistry curriculum and the corresponding syllabus emanating from it, was written out by the researchers. It was termed ‘Instructional Treatment Manual (ITM). The ITM was typed into the computer by the researchers, and copies were made and given to three experienced secondary school chemistry teachers for thorough scrutiny. This was to ensure that it adequately covered the topic, and that there was no misrepresentation of scientific facts. The input of the teachers was taken into consideration and the document was thoroughly revised to ensure its validity. The ITM provides an overview of redox reactions at the beginning. This provides the necessary prerequisite knowledge of oxidation and reduction reactions, which are the basis of electrochemistry. The ITM document describes the nature of electrochemical and electrolytic cells, and the various types of each that are available. Differences between electrochemical and electrolytic cells were also highlighted. The manual explains the electrolysis of some compounds, Faraday’s laws of electrolysis, as well as the uses of electrolysis. Some practice exercises were also included in the manual. After this exercise, the ITM was transformed into a computer instructional package suitable for classroom instruction, with the assistance of a computer scientist who is highly knowledgeable in this area. The researchers provided specific layout instructions to the computer scientist on how each item in the ITM was to be presented in the package. The development of the ECIP required the use of a personal computer, a laptop, a headphone, and empty CD-ROMs. It was produced in an html format using Macromedia Dreamweaver 8 as the overall platform. Other computer programs that were also utilized during the development process are CorelDraw graphics suit 12, Microsoft Word 2003, Macromedia Fireworks 8, and Macromedia Flash 8. CorelDraw and Microsoft Word were used for texts and graphics, Macromedia Fireworks was also used for specific texts and graphics, and for buttons while Macromedia Flash was used for the simulations.

Procedure for Validating the Electrochemistry Computer Instructional Package.

The validation of the ECIP was carried out in four stages:

Stage 1: Consultant (Expert) validation; Stage 2, one-to-one validation with students; Stage 3, small group validation with students and Stage 4, field trial validation with students.

Student participants for stages 2, 3, and 4 of the validation were selected in accordance with the generally accepted recommendations of Dick, Carey, & Carey (2005). Accordingly:

1. One-to-one stage (clinical evaluation): - a minimum of three (3) students representatives of the target population. Five students were involved in this stage.

2. Small group stage: - a minimum of eight (8) students, and a maximum of twenty (20) students representative of the target population. 10 students were involved in this stage.
3. Field trial stage: - about thirty (30) students, representative of the target population. This stage involved 30 students.

Six instruments were used to validate the ECIP. These are:

1. **Subject Content Validation Questionnaire-1.** This instrument was administered to three secondary school chemistry teachers to ascertain the adequacy of the content of the ECIP with regards to the officially prescribed content of the Nigerian Senior Secondary School chemistry curriculum. This contained eight statements to which respondents were required to state whether they strongly agreed, agreed, strongly disagreed or disagreed. Respondents responded to statements regarding the adequacy and appropriate sequencing of the contents, appropriate language use among others.
2. **Computer Expert Validation Questionnaire-2**. It was administered to two computer experts after they had gone through the ECIP, for their opinions and suggestions. They were expected to write freely about their views about the typography, legibility, navigation, and the simulation properties among others, of the instructional package.
3. **Students' Interview protocol** (Interview questions).This was used to conduct a structured interview with five students that were involved in the first stage of the validation process. It sought for reactions of the students to the ECIP as a medium of electrochemistry instruction and also to identify and remove the obvious errors in the ECIP. It asked specific questions on the clarity of the instructional package, the impact of the package on students' understanding, and the feasibility of using the package for electrochemistry instruction.
4. **Educational Technology Expert Validation Questionnaire-3** .This was designed for two educational technology experts for the purpose of finding out whether the ECIP conforms with acceptable standards in educational technology. The respondents were asked to express their opinions about the simplicity of the pages in the package, unity among the illustrations, appropriate use of colours etc.
5. **Students' Response Questionnaire-4** (Interview questions for small group, and large group field trial validation). The instrument was administered to the 10 students who were involved in the small group stage, and the 30 students who were involved in the field trial stage of evaluating the ECIP. It was designed to inquire about the quality of the ECIP as a medium for electrochemistry instruction. The instrument contained nine statements to which respondents were to state whether they strongly agreed, agreed, strongly disagreed or disagreed. The statements include those regarding the efficiency of the instructional package in terms of gaining students attention, allowing for easy students' comprehension, appropriate colour presentations etc.
6. **Electrochemistry Concept Assessment Test (ECAT).** This was a performance test instrument drawn to find out whether the students actually understood the electrochemistry concepts they were taught using the ECIP. This was designed to find out the performance level of the students when taught electrochemistry using ECIP.

All the four questionnaires, and the Students' Interview protocol were validated by referring them to three Science Education experts at the University of Ilorin. The reliability of the questionnaires was determined using the test re-test method with samples different from those used for the main study. Using the Pearson Product Moment Correlation Coefficient, the questionnaire instruments were found to have reliability values of 0.81, 0.79, 0.85, and 0.76 respectively. Also, the Electrochemistry Concept Assessment Test ECAT was validated by referring it to three experienced secondary school chemistry teachers. They were to provide their views and recommendations on the test items in terms of quality and appropriateness of its content for the purpose for which it has been designed. Thereafter, a pilot study was conducted by administering the ECAT to a group of 25 final year students in a secondary school different from the schools used for the main study. The scores that emanated from the administration of the ECAT were used to determine the reliability of the instrument. The split-half method as well as the Pearson Product Moment Correlation Coefficient was used for analyzing the scores. The result gave a reliability value of 0.82.

Consultant (Expert) validation: The original copy of the instructional package ECIP was given to two computer experts, and two educational technology experts all of whom were purposively selected, to go through for their appraisal and criticism. Their responses were qualitatively analysed, and necessary corrections as recommended by them were taken into consideration in producing the final version of the instructional package.

One-to-one validation: The stage of the validation of ECIP was carried out at Adesoye college, Offa. This school was purposively selected for the study because it had the necessary facilities for which the instruction using ECIP could be carried out. For instance, the school had a standard computer laboratory which could accommodate 30 students, each one on a computer. This validation was carried out to provide the researchers with a first hand glimpse of the feasibility of using the ECIP for electrochemistry instruction. Five randomly selected Senior Secondary School II (SII) science students formed the subjects for this stage of validation. The subjects were guided to navigate through the entire package, after which they were taught selected sub-topics in electrochemistry using the ECIP. The entire process was carried out during a double class period which lasted one hour, forty minutes. The researchers looked out for evaluation criteria such as sentence complexity; illustrations and demonstrations, how easy or difficult the students learned using the ECIP, how satisfied the students were and the ease with which they operated the software program. An oral interview was conducted for the students at the end of this stage using Students' Interview protocol. A report of the outcome of the one-to-one trial validation was made through the researchers' observations and the oral interview that was conducted at the end of the trial. Conspicuous pitfalls in the ECIP, as revealed by this stage of validation were addressed by revising the ECIP, in accordance with the researchers' report from the one-to-one trial. For instance, the software and hardware requirements for operating the package were made the first page of the package.

Small group validation: This stage of validation was aimed at determining the effectiveness of the changes made to the ECIP after the preceding one-to-one validation. This stage of validation was carried out using students in a different but equivalent school: Sapati International School, Ilorin. The school was purposively selected based on the fact that the facilities for which the study could be carried out were available there. The permission of the principal was sought to conduct the study. Ten (10) randomly selected Senior Secondary School II (SSII) science students participated in this stage, which was conducted in the school's computer room. The students were guided to navigate through the entire package, after which they were taught the same selected sub-topics as in the one-to-one validation stage, with ECIP as the instructional tool. The instruction was done over a period of two hours but there was a ten minutes break at the end of the first one hour. The researchers took note of problems encountered during the lesson, as well as the impact the ECIP made during and after the instruction. After the instruction, Students' Response Questionnaire-4 was administered to the students who were to respond in writing. The questionnaire was retrieved from them immediately they finished with it. The qualitative data obtained from the students was critically analysed. Percentage was used to analyse the quantitative data obtained from the students in their responses to the statements in

Students' Response Questionnaire-4. The researcher's observations and the responses of the participating students were used to revise the ECIP for the final stage of validation.

Field trial validation: This stage was aimed at determining whether the changes made in the ECIP after the small group validation stage were effective, and also to see whether the ECIP could be used for instruction in practice. It was carried out at Adesoye College Offa. An intact class comprising of 30 students was used for this stage of the study. The participating students were taught electrochemistry using the ECIP over a period of four lesson periods in week. Each of the periods was 50 minutes in duration. At the end of this stage, Students' Response Questionnaire-4 was administered to the students and retrieved immediately they had responded to it. They were also examined using the Electrochemistry Concept Assessment Test. This was used to find out their performance level in electrochemistry when taught using the ECIP as the medium of instruction. The qualitative data obtained from the students was critically analysed. Percentage was also used to analyse the quantitative data obtained from the students in their responses to the statements in Students' Response Questionnaire-4. Their scores in the Electrochemistry Concept Assessment Test (ECAT) was also analysed using the mean, and percentage. These were further used to determine the performance level of the students in electrochemistry, when taught using ECIP. Students' performance levels were categorized according to the common standard used in Nigerian secondary schools as follows:

Below 40% - Very poor
41% - 49% - Poor
50% - 59% - Good
60% - 69% - Very good
70% - 100% - Excellent.

The focus of this study was limited to finding out the performance level of students when taught electrochemistry using the ECIP, and not to compare the use of ECIP with any other teaching strategy. Therefore, a test of the difference in achievement between the use of ECIP and any other teaching strategy was considered a subject of further research.

RESULTS

Subject content validation

The subject content validation of the Electrochemistry Computer Instructional Package (ECIP) was carried out using Subject Content Validation Questionnaire-1. The result obtained from the administration of the questionnaire showed that the three teachers to whom the questionnaire was administered strongly agreed with every statement in the questionnaire. They however indicated that the corrections they made while reading through the final product should be implemented and this was done as deemed fit by the researchers. The first statement on the questionnaire was that the content of the instructional treatment manual (ITM) adequately covered the electrochemistry content of the official secondary school chemistry syllabus. They all strongly agreed with it .The fact that all the three teachers strongly agreed to this statement indicated that the subject matter content of the ECIP adequately and sufficiently covered the electrochemistry aspect of the Nigerian secondary school chemistry.

Expert validation

Two categories of experts were involved in the validation of the ECIP. They were: computer, and educational technology experts. Validation by computer experts was based on the following criteria: typography, legibility, navigation, interface, simulations, functionality, packaging, and durability. Two computer experts were involved and they were of the opinion that the typography of the instructional package was good enough. They recommended that some of the font sizes should be increased but also noted that the legibility of the content of the package was good. They also stated that the navigation was good. While one of the experts emphasized that the overall interface of the design was very good, the second expert stated that it was user friendly. They both claimed that the simulations were good, and that the links worked well in terms of functionality. The packaging was judged to be excellent by one of the experts, while the other said it was good. They also both emphasized that the package was durable considering the storage media that was used.

Validation by educational technology experts was based on the following criteria: simplicity, unity among illustrations, emphasis on key concepts, colour use, and text. Written responses and verbal contributions were obtained from the two experts. The two of them stated that the concept of electrochemistry has been very well simplified even though one of them suggested the inclusion of audio explanations in some cases to further enhance individualistic learning. They both expressed that there was unity among the illustrations. However, while one of the experts believed that key concepts were sufficiently brought to the fore with simulations of the movement of ions within the electrolytes, the other expert recommended more emphasis on key concepts. Furthermore, one of them agreed that the colour use was appropriate while the other suggested a change in some of the background colours. One of the experts also said that appropriate texts were used, while the other recommended that the font size of some texts should be increased. In an overall judgement on the package, one of the experts stated that it was an innovative development in the design and validation of instructional packages. The other expert stated that the package could enhance learning especially if the little details he had expressed concern about were appropriately implemented. On the basis of the comments and suggestions of the experts, some text fonts were increased, while some background colours were also changed. During the review of the package after expert validation, some text fonts were increased, and some background colours were changed as recommended by the experts.

One-to-one validation with students

The criteria used in the one-to-one validation with students were clarity; impact on learner; and feasibility. The students responded that the vocabulary used in the package was clear, and that the messages were easy to comprehend. They also stated that the content was sequential and the illustrations were good. They emphasized that the examples given in various cases were relevant and adequate, and that simpler concepts led to more complex ones. With respect to the impact it had on the learners, they responded that they understood the concepts better, learnt well with the package and that they were satisfied with the skills and knowledge they acquired from the package. They further stated that they were better motivated to learn, and that they had learned better using the computer package than the conventional lecture based teaching they had always been used to. Concerning the feasibility of using the package, the students said their own environment was conducive enough to utilize the package, and that the time spent in using the package was adequate. They claimed that in the computer laboratory where the lesson was held, the equipment used were adequate except for the fact that not all the computer systems had multimedia speakers. The students expressed their optimism about the possibility of many schools in Nigeria to be able to use computers for their science lessons. The students were unable to identify any major problem associated with the use of the package apart from those peculiar to the computer systems. For example, one of the computer systems kept restarting itself. The major defect identified on the computer package during this stage was that the hardware and software requirements for operating the package were not provided in the package. As a result of this, the package could not be run on some systems. This was due to the fact that the systems lacked the necessary hardware or software for running it. In revising the package after the one-to-one validation, the hardware and software requirements for operating the package was made to be the first page in the package so that users can know whether it would work well on the system they want to use to run it. Some spelling errors were also corrected at this stage.

Small group validation

Small group validation was carried out with ten students as subjects. The researchers observed that there were some sentence errors, spelling mistakes and misrepresentation of symbols in the package. Some paragraphs and formatting errors were also discovered. After the students had been taken through the computer package and taught selected sub-topics on electrochemistry with it, the result obtained from their responses to Students' Response Questionnaire-4 as shown on table 1, and analysed accordingly.

Table 1: *Table of the result of students' response to Students' Response Questionnaire-4, for small group validation*

S/N	STATEMENT	RESPONSE/ 10 STUDENTS			
		Strongly agree	Agree	Disagree	Strongly disagree
1	The instruction using the software held my attention more than the method my teacher uses to teach me.	6	4	0	0
2	The messages in the package are easy to understand	3	7	0	0
3	The content of the software has been well sequenced	4	4	2	0
4	The illustrations in the software are very clear to me.	8	2	0	0
5	The examples used in the various cases in the software are very relevant.	5	5	0	0
6	There is a proper transition between concepts ie. Simple ones lead to more complex ones	5	5	0	0
7	The colours used for the various presentations are quite appealing.	2	8	0	0
8	The tests and exercises in the software measure the knowledge and skills taught.	4	5	1	0
9	I prefer the use of this instructional method to the method my teacher uses to teach me.	**7**	**1**	**2**	0
	Total	**44**	**41**	**5**	0

From table 1, the overall total students' response to the statements = 44 + 41 + 5 + 0 = 90.
Total response (Strongly agree) = 44
Percentage response (Strongly agree) = (44 ÷ 90) × 100% = 48.9%
Total response (Agree) = 41
Percentage response (agree) = (41 ÷ 90) × 100% = 45.5%
Total response (Disagree) = 5

Percentage response (Disagree) = (5 ÷ 90) × 100% = 5.5%
Total response (Strongly disagree) = 0
Percentage response (Strongly disagree) = (0 ÷ 90) × 100% = 0%
Total positive response (Strongly agree and agree) = 44 + 41 = 85
Percentage positive response (Strongly agree and agree) = (85 ÷ 90) × 100% = 94.4%.
Total negative response (Disagree and strongly disagree) = 5 + 0 = 5
Percentage negative response (disagree and strongly disagree) = (5 ÷ 90) × 100% = 5.6%.

From the free comments of the students about what they would like to be improved in the package, some of them indicated that they would like computer instructional packages to be produced for other topics in chemistry, and even in other subjects. They requested the package on CD-ROM and to be widely distributed so that they can have personal copies. The respondents also indicated that all the computer systems to be used for instruction using ECIP should be provided with multimedia speakers.

After the small group validation, some sentence errors, spelling mistakes and misrepresentation of some symbols in the package were corrected. Some paragraphs and formatting errors discovered were also corrected.

Field trial validation with a larger group of students.

The results obtained from the administration of Students' Response Questionnaire-4 to the thirty (30) students after they had been taught using the computer package is presented in table 2. The analysis of the table follows.

Table 2: *Table of the result of students' response to Students' Response Questionnaire-4, for field trial validation.*

S/N	STATEMENT	RESPONSE/ 10 STUDENTS			
		Strongly agree	Agree	Disagree	Strongly disagree
1	The instruction using the software held my attention more than the method my teacher uses to teach me.	17	12	1	0
2	The messages in the package are easy to understand	13	16	1	0
3	The content of the software has been well sequenced	15	14	1	0
4	The illustrations in the software are very clear to me.	22	8	0	0
5	The examples used in the various cases in the software are very relevant.	19	11	0	0
6	There is a proper transition between concepts ie. Simple ones lead to more complex ones	17	13	0	0
7	The colours used for the various presentations are quite appealing.	16	13	1	0
8	The tests and exercises in the software measure the knowledge and skills taught.	18	12	0	0
9	I prefer the use of this instructional	18	10	2	0

	method to the method my teacher uses to teach me.				
Total		**155**	**109**	**6**	0

From table 2, the overall total response to the statements = 155 + 109 + 6 + 0 = 270.
Total response (Strongly agree) = 155
Percentage response (Strongly agree) = (155 ÷ 270) × 100% = 57.4%
Total response (Agree) = 109
Percentage response (agree) = (109 ÷ 270) × 100% = 40.3%
Total response (Disagree) = 6
Percentage response (Disagree) = (6 ÷ 270) × 100% = 1.62%
Total response (Strongly disagree) = 0
Percentage response (Strongly disagree) = (0 ÷ 270) × 100% = 0%
Total positive response (Strongly agree and agree) = 155 + 109 = 264
Percentage positive response (Strongly agree and agree) = (264÷ 270) × 100% = 98%
Total negative response (Disagree and strongly disagree) = 6 + 0 = 6
Percentage negative response (disagree and strongly disagree) = (6 ÷ 270) × 100% = 2%.

The general feelings of the respondents in the field trial validation were positive and very similar to those of the small group validation. However, some pointed out that the internet and other computer applications should be disabled during lessons to avoid students doing other things on the computer while the lesson is going on. Three of the students want the inclusion of an index at the end of the package to be considered. Some of the respondents also said they were satisfied with the way the package had been put together and so needed no improvement.

The implication of the results obtained from the analysis of the Students' Response Questionnaire-4 for both the small group and the field trial validation is that there was an overwhelming response of users in favour of the Electrochemistry Computer Instructional Package among the students who were exposed to its use. The result of the Electrochemistry Concept Assessment Test conducted for the students during the field trial validation is presented in table 3.

Table 3: *Students' performance in the electrochemistry concept assessment test*

Student	Score/ 25	Percentage
1	18	72
2	19	76
3	11	44
4	10	40
5	08	32
6	18.5	74
7	19	76
8	18.5	74
9	14	56
10	21.5	86
11	18.5	74
12	12	48
13	13	52
14	19	76
15	09	36
16	14	56

17	19	76
18	17	68
19	12	48
20	10.5	42
21	18	72
22	14	56
23	22.5	90
24	19	76
25	20.5	82
26	12.5	50
27	20	80
28	19	76
29	19	76
30	20	80
Average	**16.2**	**64.8**

From table 3, the average score of the students out of a maximum score of 25 is 16.2. This translates to 64.8%. To make a conclusion about the performance level of students in electrochemistry when taught using ECIP, the interpretation of the result was based on the following grading which is commonly used in Nigerian secondary schools.

Below 40% = Very poor
41%-49% = Poor
50%-59% =Good
60%-69% =Very good
70%-100% = Excellent

Since the average percentage score of the student is 64.8%, the conclusion therefore is that when students were taught electrochemistry using ECIP, their performance level was very good.

DISCUSSION

The findings earlier reported shows that teachers strongly agreed that the subject matter content of the ITM covered the electrochemistry aspect of the secondary school chemistry adequately. Such a strong positive agreement to the statement is crucial for the successful execution of the research work since the instructional package designed was meant to cover electrochemistry as a topic in secondary school chemistry. A favourable response to this statement was fundamental to the further execution of the research, so as to ensure that the content of the ITM on electrochemistry was carefully prepared. All the teachers who responded to the Subject Content Validation Questionnaire-1 strongly agreed that the sub-topics treated in the ITM were sequentially arranged. This sequential arrangement of the sub-topics is considered to be vital to the ease of using the instructional package to teach. It is also crucial to the propensity of the students to be able to understand the concepts taught. In addition to responses by the teachers, the overall response of the students in both the small group and the field trial validations indicated that the content of the ECIP has been well sequenced. For the small group validation, out of 10 respondents, four strongly agreed to the statement while four agreed, and two disagreed while none of them strongly disagreed (see table 1). In the field trial validation, out of 30 respondents, 15 strongly agreed to the statement while 14 agreed, and 1 disagreed (see table 2). If the sub-topics had not been sequentially arranged, from simple to complex ones, it would probably have created a lot of confusion for the students in learning.

To give validity to the ECIP, it was necessary to have educational technology experts review the package. Their professional assessment and input were necessary in providing some confidence that the package would make the desired impact on the learners. Their suggestions which were implemented in revising the package, as well as their favourable comments went a long way in ensuring the validity of the ECIP. In addition, their positive responses and input indicated that the package conformed with the ideals of educational technology.

The primary goal of this research was to produce a computer instructional package that is suitable for teaching and learning electrochemistry so that students' performance in the topic could be enhanced. Table 3 summarises the scores of 30 students in a test conducted for them after they had been taught using ECIP. An average score of 64.8% was obtained, which translates into a very good performance level. This suggests a high degree of validity for the package.

As at present, indigenous computer instructional packages on chemistry and other subjects are not readily available in Nigeria. This is due to the fact that the country is still undergoing a process of technological development in the area of ICT. Consequently, the production of instructional packages, and their corresponding utilization for instruction in our educational system is not widespread. As a result of this, research into the design and development of computer instructional packages, and their utilization for classroom instruction is scarce.

CONCLUSION

The results obtained from the analyses of the data gathered in this research indicated that the content of the Electrochemistry Computer Instructional Package (ECIP) as developed covered the electrochemistry aspect of the Nigerian secondary school chemistry adequately, and that it was also sequentially arranged. The result further showed that the package conformed with acceptable standards of educational technology. Besides, the performance level of students when taught using ECIP was very good. It is hoped that the utilization of this package for electrochemistry instruction in our secondary schools will enhance the understanding of the topic, and hence improve students' performance in their Senior School Certificate Examination. Based on the findings of this research work, it is recommended that computer instructional packages such as the ECIP should be produced for all the other topics in the Nigerian secondary school chemistry curriculum, especially the difficult ones. This could be cooperatively done by teachers, researchers, students, or educational technologists.

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