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The Development of Mathematics E-Learning Tool for Nigerian Senior Secondary Schools

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Abstract

Electronic learning (E-learning) involves the use of information and communications technology (ICT) tools and systems in teaching and learning processes. Such tools are being rapidly deployed into the Nigerian higher educational system because of their pedagogical benefits. But there have been inadequate efforts to deploy such tools at the secondary schools in the country, where spectres of over-populated classrooms and escalating student-to-teacher ratios have contributed to the poor performances of students in the Senior Secondary School Certificate examinations, especially in mathematics. Towards contributing to the local Nigerian efforts in the development and utilisation of e-learning tools in Nigerian secondary schools, this research undertook the development of an e-learning application (E-Maths) to support the teaching and learning of some aspects of the mathematics syllabus of the West African Examinations Council. A survey of students in selected secondary schools had revealed that mathematics was the most challenging to learn. The research found out and recommended that, in view of the very limited networked and Internet-connected ICT infrastructure available to most Nigerian secondary schools at present, the application would be most useful in hybrid learning environments that combine face-to-face classroom instruction delivery with the application, using CD-ROM as the delivery medium.

Keywords

Electronic learning, Learning management system, Mathematics, Secondary education,

Introduction

The expansion in the ways Information Communications Technologies (ICTs) are being deployed has transformed virtually every sector of the world's growth and development. In particular, different ICTs are being rapidly integrated into educational systems in developed countries, and gradually in developing countries. Electronic learning (e-learning) refers to the use of various ICTs in teaching and learning and related education management processes. This may involve the use of generic software, such as word processors, spreadsheets, or graphics, statistics, email, web browsing or multimedia software on equally generic desktop computers or mobile devices such as mobile phones and tablets. It is increasingly also involving the use of computer-assisted instruction (CAI), computer-managed instruction (CMI) software or learning management systems (LMS) which are designed specifically to facilitate the delivery of, access to or management of the teaching and learning of some specific subjects. Such software is also increasingly being deployed and used in networked environments, such as campus or school networks, or the Internet. E-learning provides a flexible and potentially more efficient learning environment than traditional classrooms for rapidly growing and diverse communities of learners.

Ajelabi and Agbatogun (2010), citing Okebukola (2004), note that with the implementation of the UBE (Universal Basic Education) scheme in Nigeria, as many as 14 million students are expected to be enrolled into Nigerian secondary schools from 2008, out of the estimated population of 140 million of the country in 2006. In view of the expected explosion in enrolments and consequent increases in students-to-teacher ratios in classrooms, it has become necessary for education policy makers and school systems in the country to begin to harness effectively the opportunities that e-learning systems provide for tacking the challenge.

Problem Statement and Objectives

A number of Nigerian government secondary schools, many of which are located in rural areas, are geographically and socially isolated. Their students are often from low to middle income families, and this hampers the ability of the students to acquire text and reference books. Moreover, there is inadequate number of teachers of mathematics in these schools. For instance, in a community secondary school in Ibadan (Isebo Community Secondary School, Ibadan, Nigeria) where the lead author of this paper had volunteered as Mathematics teacher, it was observed that the school had just one transient National Youth Service Corps teacher handling all the three senior secondary arms in the school.

As Recesso (2001) pointed out, the various challenges that confront educational systems in developing countries, such as inadequate and poorly motivated teachers, inadequate books and poor learning environments, have collective adverse effects on student learning and achievement. The resultant poor performance for instance, is more critical in science and mathematics subjects. Recently, the West African Examination Council announced at a media briefing that out of the 1,135,557 students that sat for the May/June 2010 exams in Nigeria, only 337,071 or 24.94% obtained credits in subjects that included English Language and Mathematic, and that the 2009 result was only one per cent better (The Punch Newspaper, 2010). Considering the importance of these two subjects, and especially mathematics in the technological development of any nation, these figures are alarming, and demand urgent action. Nigeria is not alone in this abysmal performance. Indeed, the whole of Africa is affected. Lujara, Kissaka, Trojer and Mvungi (2007) reveal that for selected subjects for the years 1994 – 2005 in Tanzania, the average failure rates were more than 40%. Performance in mathematics was worst, with an average failure rate of 70%.

These challenges however provide broader lens of considering the potential use of ICT in education. In Nigeria, most private and many public secondary schools have acquired desktop computers for their students' use, although most of the computers lack appropriate computer-assisted or computer-management software, or content management systems for the teaching and learning of specific subjects in line with approved syllabuses. This research sought to contribute to solving the paucity of such ICT-based tools by designing a Mathematics e-learning tool that makes effective use of the limited available ICT resources in Nigerian secondary schools to improve the teaching and learning of Mathematics. The research aimed to develop a system that provides appropriate (i) modules for the update and use of learning materials on specific topics in secondary school mathematics; (ii) modules to manage users of the system when installed on a computer system or network; (iii) modules for monitoring and assessing students' learning progress; and (iv) mechanisms for protecting the database and the information stored.

Literature Review

E-Learning

According to Salawudeen (2006), Electronic Learning (E-Learning) technology is the convergence of learning process and the Internet, that is, online knowledge acquisition through the Internet or offline through a CD-ROM, cassette player or other means of storing digital audio or video. E-Learning can also refer to educational websites such as those offering learning scenarios, worksheets and interactive exercises for youths and children. Citing Hedge and Hayward (2004), Gunga (2010) posits that e-learning is an innovative approach for delivering electronically mediated, learner-centred and interactive learning environments to anyone, anyplace, anytime by utilizing the Internet and digital technologies..

Obashoro-John (2007) also notes that effective e-learning presupposes the ready availability and ready access by learners and teachers to the following technologies: multimedia CD-ROMs, MP3 players, websites, discussion boards, emails, computer-aided assessments, learning management software, blogs, etc. E-learning is often considered as a means of permitting access to learning by using any or all of the following technologies: TV, mobile phones, webcam, email, DVD/CD, audio/video tape, website, telephone, audio-conferencing, video conferencing, podcasting.

Allan (2008) highlights the expansion in the language of e-learning, along with some differences in opinions on what should or should not be considered as components and resources for e-learning. Some

researchers hold the opinion that e-learning should not necessarily exclude the use of printed text for the delivery or access to learning materials. Others believe that inclusion of the Internet is not essential. Nevertheless, simply providing passive learning material that is electronically based, such as a PDF documents posted on the Internet, is not commonly considered e-learning, as it is similar to the simple provision of textual material with no opportunity for learners to ask questions or to enter into discussion.

Nichols (2003) contrasts e-learning with online learning and blended learning. He explains that online learning entails the use of e-learning tools in a distance education mode using the Web as the sole medium for all learning and student-teacher contact. He defines blended learning (also known as mixed-mode or resource-based learning) as an approach to education that combines face to face and distance approaches to education in which an instructor meets with students (either in a face to face mode or through a technological means) along with technology-delivered and accessed resource-base of content materials and learning activities for the use of the students.

Rationale, Challenges and Principles of E-Learning

Alexander (2001), citing Bates (1997), advances four reasons for using technology in higher education: to improve the quality of learning; to improve access to education and training; to reduce the costs of education; and to improve the cost-effectiveness of education. The following advantages of E-Learning compared to traditional classroom learning are often highlighted in the literature: cost savings, geographical reach, extensive use of multimedia, availability, portability, consistency, learner control, up-to-date content, no duplication, and shorter learning time (http://www.study-center.com/welearn.asp). Nevertheless, often also highlighted, as noted by DelVecchio and Loughney (2006), are the following challenges for students, teachers and educational administrators in the E-Learning environments: demand on teachers and students for adequate computer skills and effective online communication and writing skills; costs of ready and frequent access to and use of computers and the Internet on students; students' sense of isolation from their teachers and education systems; demand for students' self-motivation and drive to learn independently of the teacher; initial heavy demand for content development skills and time from teachers and instructors.

Content Management Systems

The earlier software tools for the learning and teaching of specific subjects and topics were known as Computer-Assisted Instruction and Computer Managed Instruction tools. However, the ultimate educational tools today are educational Content Management Systems (CMS), or more specifically, Learning Management Systems (LMS). All LMS, such as the commercial Blackboard and the open source Moodle (open source), share some common features. As explicated by Blackboard (2007, 2008), Rice (2006) and Cole and Foster (2007) for the Blackboard LMS and Moodle LMS respectively, the users are expected to use their browsers to navigate to the website of the LMS and log-in. There is usually a list of available classes that the student can click to access. That will load the virtual classroom in the student's browser. Here the student will access the various resources uploaded by the teacher starting from the syllabus and including lecture notes, articles, presentations, videos, images, web links and other types of files. There will be an area where the students can upload their assignments. Usually a discussion board is included, an area where the students can check their grades. There may be a calendar and support for Internet chat, email, and word processing. The LMS could contain parts that do not require the interaction with the teacher such as quizzes that are checked and graded by the LMS itself.

A major drawback of commercial LMS, such as Blackboard, is their high cost of acquisition and update. On the other hand, the commercial LMS are much significantly easier to use or manage than some free solutions. For most schools and universities, the popular open source choice is often Moodle LMS. In December 2010, there were 50,630 registered Moodle eLearning sites, 4,114,823 courses, and 39,381,043 users speaking over 70 languages (http://moodle.org/stats). Another open source alternative is Drupal, a free content management software distributed under the terms of the General Public

License that can be used to organise, manage and publish content in wide variety of environments. Although Drupal's user community is much less in size (630,000+ at 2012, http://www.drupal.org/) than claimed by Blackboard and Moodle, it is being used by organisations in a variety of sectors, including education. Another option is to build a "home grown" CMS, using freely available development tools. If the institution or school has in-house skills or is willing to hire outside contractors, a CMS could be built using, for example, Linux as the operating system, Apache as the web server, PHP as the programming language, and MySQL as the database engine. But such an approach can also be very expensive in terms of development time and resources.

E-Learning Opportunities and Trends in Africa

Lundy and Logan (2002) in exploring the key trends in E-Learning in Africa note that governments in emerging economies see e-learning as an attractive option for delivering the skills of the developed world to the developing one. They note that as fifty per cent of African countries have deregulated their telecommunications industries, which would be more infrastructure investment, improved telecommunications services, and greater prospects for e-learning initiatives and projects. They conclude that e-learning will become an imperative strategy for enterprises and governments to reskill, retool and generally keep pace with the changing technological and business environment.

However, despite the several reported positives of e-learning in developed countries, Gulati (2008), citing Leary and Berge (2006), stated that a review of 150 distance education programmes in sub-Saharan Africa revealed that traditional, paper-based means of distance learning are more reliable, sustainable, and widely used than online and Web-based methods. Gunga (2010) explains the situation in terms of the following challenges of e-learning in African schools: non inclusion of regular 'technology education' and 'technology teacher education' as core requirement in many systems of education in African countries; getting stuck in traditional teaching methodology due to static national policy on ICT, technology (teacher) education and digital inclusion; the costs of personal computer, laptop, software, Internet access and their technical support are high; although mobile technology is gaining ground widely, associated with it is high cost of usage, small screen size and low life of battery; inadequate or unreliable of electricity power supply in both urban and rural areas. Despite these and other challenges, Lundy and Logan (2002) opine that "e-learning opportunities need not depend on these changes or wait for them. Much of the infrastructure to deploy basic e-learning - sometimes only a stand-alone PC is required - exists in Africa right now."

There have been reported advances in e-learning in some African countries. Kalinga (2008) describes her work on the Development of an Interactive e-Learning Management System (e-LMS) for Tanzanian Secondary Schools. Lating (2006) reports a similar project in Uganda, describing the use of CD-ROMs to deliver learning material to schools without Internet connection in a "hybrid E-learning" which includes both on-line and off-line material. The hybrid E-learning project includes development of physics/chemistry/mathematics courseware out of local content (school teachers') materials and lecture notes, development of courseware for delivery through the Internet, making and delivering CD-ROMs to the schools.

E-Learning of Mathematics

The use of Virtual Learning Environments (VLEs) for the teaching of mathematics has been described in the scientific literature. For example Chinnappan (2006) for WebCT™ (now Vista), McClendon and McArdle (2002) for a system called ALEKS, while Dougiamas and Taylor (2003) investigated on-line classes that were built using the Moodle Content Management System (CMS). Moodle, Dillenbourg, Schneider, and Paraskevi (2002) discussed whether VLEs can really improve education and reduce its cost. The authors made the case that as with all previous technologies that were adopted by schools, it is the proper implementation of any of these technologies that will improve instruction. They stated that "media have no intrinsic effectiveness, only affordances." Chinnappan (2006) studied the implementation of WebCT for a group of beginner mathematics teachers. There are several other companies that sell CMS capable of providing on-line mathematics courses. For example, Apex Learning (http://www.apexlearning.com) sells a VLE

that provides on-line based standard mathematics courses for grades 6 through 12, as well as courses in many other subjects.

Henri-Paul Indiognie (2008), in a review of Computer-Based Learning Technologies (CBT) for the learning and teaching of mathematics, identified and reviewed GeoGebra (available at http://www.geogebra.org/cms), which he describes as a free mathematics software that covers geometry, algebra and calculus and released under public general license for education in secondary schools.

In the African context, Liverpool, Marut, Ndam and Oti (n.d.) provide a model for the implementation of courseware development for e-Learning in Nigerian higher education institutions based on their experience in implementing an e-learning project in mathematics at the University of Jos, Nigeria. Lujara et al (2007) describe their work on the introduction of Open-Source e-Learning environment and resources for the Tanzanian secondary schools in Mathematics and Science subjects. They note that in Tanzania, for secondary schools e-learning, there is only one website with URL http://www.distancelearning-tz.org which provides notes for secondary schools in different subjects, and this website is maintained by a non-governmental organisation, International Institute for Communication and Development (IICD).

Tools, Methods and Materials

The present research made use of open source software (OSS) tools to develop a mathematics e-learning application (*E-Maths*) that enables the: (i) organisation and update of mathematics learning content to a database, (ii) provision of the application (comprising the interface, middleware and database) for deployment on CD-ROM or networks, and (iii) interactive self-paced use of the content by teachers and students in a hybrid classroom-online learning and teaching environment.

The following tools, methods and materials were used during the system analysis, design and implementation, and testing and evaluation of the application:

(1) Learning theories, pedagogical principles and instructional design principles from the literature to guide the design of e-learning application;

(2) Senior Secondary School mathematics syllabus approved by the West African Examinations Council (WAEC) (for the identification of approved mathematics topics and sub-topics);

(3) Lesson Notes obtained from a sample of teachers, using a participatory content acquisition approach (for the acquisition and development of learning contents and objects);

(4) Survey observations, interviews and questionnaire (for collecting data and information during the system analysis of pre-existing infrastructure, resources, conditions and processes in selected schools in Ibadan metropolis, Nigeria;

(5) Data flow diagrams (DFD) and System Flow Charts (SFC) tools (for describing the analysed and designed system components and processes;

(6) Sharable Content Object Reference Module (SCORM) and Instructional Management System (IMS) standards (for the structuring and packaging of mathematics learning content into learning objects);

(7) Drupal Learning Management System (for the structuring, update to database and use of learning content);

(8) WAMP (Windows, Apache, MySQL, PHP) technology rack (for the development and integration of the system's user interface, middleware and database);

(9) XHTML (eXtensible Hypertext Markup Language) and XML (eXtensible Markup Language) standards and codes (for displaying and interrelating textual and multimedia learning content objects);

(10) CD-ROM (for the distribution of the application, and the associated interactive multimedia help and training files; and

(11) Survey questionnaire (for collecting system evaluation data from pilot users - teachers and students of the *E-Maths* application.

System Analysis

The system analysis step in the development of *E-Maths* involved analysing the existing mode of

teaching and learning of mathematics in senior secondary schools (SSS), identification of problems that teachers and students face, and identification of possible pedagogical and technological strategies, methods and tools for solving the problems.

Data collection

The following three survey methods were used in the investigation of the existing system:

Direct Observation: One of the researchers visited 14 different schools (10 public schools and 4 private schools) in the Ibadan metropolis to observe various activities, conditions of the classrooms, population of the classes. Also noted were the attitudes of the students and teachers to mathematics. The previous direct involvement of one of the researcher in the teaching of mathematics in a community secondary school helped tremendously.

Interviews: To authenticate the observations and the data from the questionnaire survey, the researcher conducted brief interviews of students and mathematics teachers in the selected public and private schools as the questionnaire was being completed by other sampled students. The student responses during the interviews showed that there were indeed mathematics topics that they found quite difficult to understand. Some students even had difficulty identifying the broad heading under which some topics belonged.

Questionnaire: All the 14 schools were also involved in the questionnaire survey. A short questionnaire to determine the most challenging mathematics topic was administered to sampled students and teachers. This was done in order to determine the topics that the e-learning system should focus upon. In order to ensure that the teachers did not feel threatened that the survey was questioning their capability to communicate well with their students, the researcher took the pains to explain to the teachers that the questionnaire was about identifying the subject that they had to explain over and again (and yet again) to the students before they understood (if they did). Two mathematics teachers (the average number per school) per school were sampled, for a total of 28 teachers. Furthermore, two students, a boy and a girl, from SS3 level in each of the sciences, commercial and arts classes section, for a total of six students from each school, and 74 students overall. The researcher walked the students through the student questionnaire slowly and ensured that each student completed it independently. Six students were selected from each school, randomly from the provided arm/class registers. In the very few cases where the selected SS3 students were not available they were excluded from the survey and analysis.

The surveys were carried out in March 2011, about four weeks to the start of the Senior Secondary School Certificate Examinations, and the best time to collect and elicit this kind of information, with the SSSCE timetable out, and mock examinations and preparations in full gear for the all stakeholders of the system. Accordingly, the questionnaire was designed to be simple and very short to hasten recovery time because the teachers and students were at a busy time of the school calendar.

Findings

The teaching and learning methods and conditions in the public schools that were surveyed epitomise the situation of most public schools in Nigeria. The teaching/learning infrastructure consists of wooden desks or long benches, chairs, black writing boards and white chalk. In most of the schools visited, there were as few as two mathematics teachers taking as many as four to six arms of the senior secondary school classes. This workload of the teachers was enormous, particularly as the teaching and learning of mathematics in these schools is completely manual. The private schools were ranged from being about the same to slightly and much better.

The existing system is the traditional classroom-centred, face-to-face approach, which is constrained by explosion in the number of students using the system without a commensurate increase in the number of teachers. The mathematics teachers on ground were not enough to handle effectively the numbers of students, and it is difficult for the teachers to give the individualised instruction that is fundamental to effective self-paced learning of mathematics for weak students. The interviews with teachers in the schools revealed that some of them had Bachelor of Science, not Bachelor of Education in Mathematics, degrees. Possibly because of the lack of training in educational pedagogy, these teachers were not able to determine themselves if

any topics in mathematics were proving difficult for their students to learn.

On passing the Junior Secondary School Certificate Examinations (JSSCE), students are placed in the Sciences, Commercial and Arts and Commercial arms of schools on the basis of their performances in the examinations in that order, although there are a few exceptional cases where a student with very good performance may request to be placed in Commercial or even the Arts arm. Nevertheless, the students in all arms take mathematics under the same teaching and learning conditions and methods, irrespective of their JSSCE performances.

Figure 1 shows graphically the result of the analysis, which shows that the students found "Mensuration" as the most challenging topic in mathematics, followed by "Construction", "Plane" and "Circle" in that order. Based on this particular finding, "Mensuration" was decided as the focus of the E-learning tool to be developed. Table 1, obtained from the Mathematics syllabus approved by the West African Examinations Council (WAEC), shows the sub-topics under Mensuration, which formed the scope of the learning content targeted by *E-Maths*.

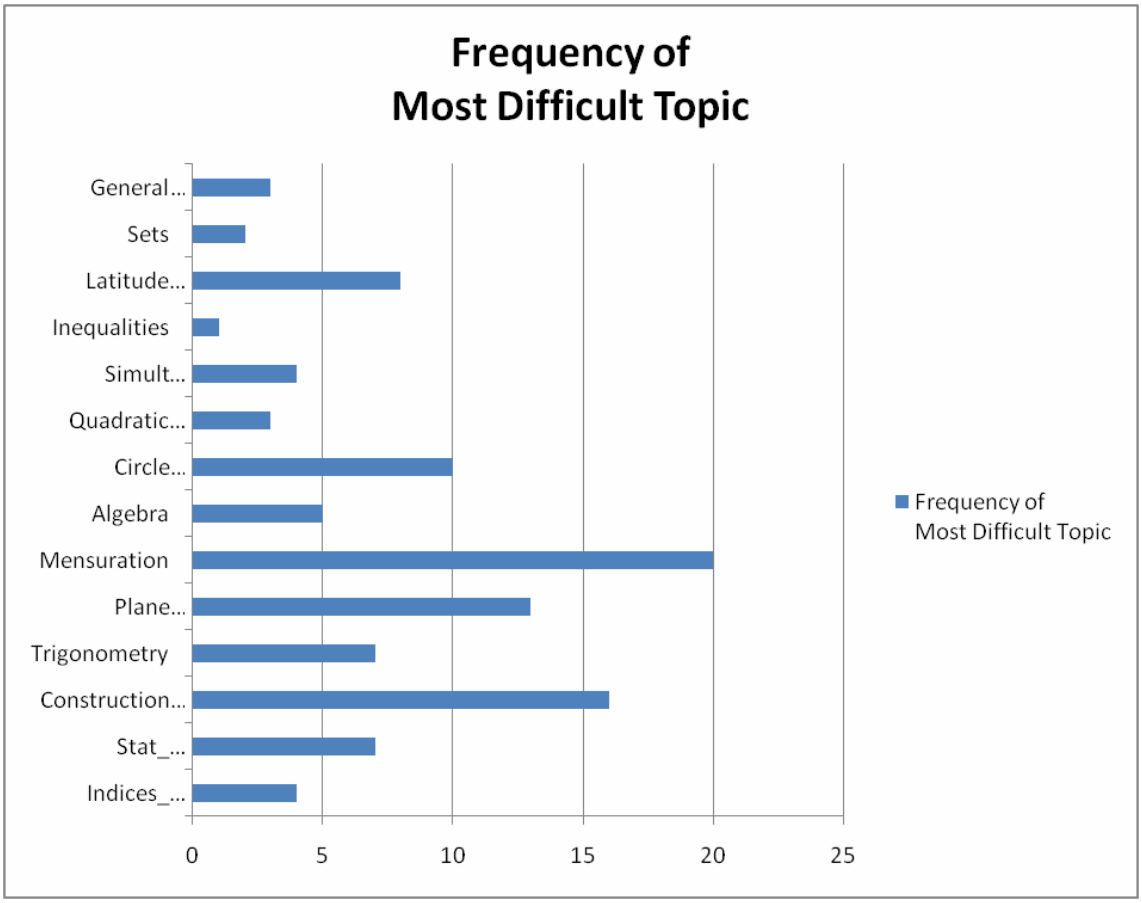

Figure 1: **Most Difficult Mathematics Topics**

Table 1: Sub-topics under Mensuration

Sub-topics	Contents	Notes
Lengths and Perimeters	Use of Pythagoras theorem, sine and cosine rules to determine lengths and distances.	No formal proofs of the theorem and rules are required.
	Lengths of arcs of circles. Perimeters of sectors and segments.	
	*Latitudes and Longitudes.	Distances along latitudes and longitudes and their corresponding angles.
Areas	Triangles and special quadrilaterals – rectangles, parallelograms and trapezia.	Areas of similar figures. Include area of triangles is ½ base x height and *1/2 abSin C. Areas of compound shapes.
	Circles, sectors and segments of circles.	
	Surface areas of cube, cuboid, cylinder, right triangular prisms and cones. *Spheres.	Relation between the sector of a circle and the surface area of a cone.
Volumes	Volumes of cubes, cuboid, cylinders, cones and right pyramids. * Spheres.	Volumes of compound shapes.
	Volumes of similar solids	

System Design

Systems design refers to the process and the steps that are involved in defining and articulating the components, modules, interfaces and data requirements needed for a system to satisfy specified requirements.

Design Philosophy and Objectives

The design philosophy aimed for a self learning environment to help students get control of a subject even in the absence of a teacher or during self study. The user interface was designed using instruction design principles to provide this facility. The design of the application aimed for specified target objectives for teachers and students of mathematics and the technical support personnel. For schools and mathematics teachers, the design objectives are: (i) inexpensive development (all the software needed for the creation of the mathematics e-learning tool should be available cheaply); (ii) rapid creation (teachers should be enabled to create their own e-learning content rapidly with the application). For mathematics students, the specified target objectives are: (i) ease of use (it should be very easy for a below average student to select a learning object module, learn the content, and assess him/herself; (ii) self-paced learning (the student can repeat a module as many times as are needed for him to understand any particular topic); (iii) improvement of students performance in mathematics, which is ultimately what the application aims to achieve. For the technical support staff that may be available in schools, the design objectives are: (i) shortened time needed for multimedia programming; (ii) ease of maintenance; (iii) flexible distribution and deployment through CD-ROM or networks.

Instructional Design

As the application is intended to deliver learning content, the directing principles and strategies for the content capture, storage, processing and presentation aspects of the design is Instructional Systems Design (ISD). ISD refers to the systematic guidelines instructional designers follow in order to create and deliver a workshop, a course, a curriculum, an instructional program, a training session, or the instructional materials and products for educational programs.

The design of the content delivery aspect of *E-Maths* was based on the core principles of the ADDIE (Analysis, Design, Development, Implementation, Evaluation) generic model for instruction system design (Molenda, 2003; Rao, 2010), and took into consideration the following: building on existing abilities and motivations of the students to pass mathematics and to use technology; creating challenges of increasing difficulty; adjusting the level of interactivity to accommodate the computer neophyte; provision of a means of measuring progress (assessment); incorporation of direct manipulation of elements (learning objects) by learners where possible; provision of sufficient review and practice; use of graphic elements to create an attractive, memorable and distinctive context.

Courseware Design

The system analysis revealed that the learning content provided by teachers of mathematics to their students are organised in lesson notes, with each lesson note structured into the following hierarchical levels of content: (1) Subject (i.e. Mathematics); (2) Topic (within subject); and (3) Sub-topic (within Topic).

In turn, each sub-topic has the following sections: (i) Reference Book (a textbook that provides the source of guidelines and content); (ii) Teaching aids (to be used by the teacher in the delivery of the content), (iii) Previous knowledge (usually in the form of preliminary questions or exercises to ascertain essential prerequisite knowledge); (iv) Objectives (i.e. learning objectives); (v) Introduction (this is usually a brief introduction to the topic, including scenario description to establish the importance of the topic and motivate the learners); (vi) Steps (i.e. specific instructional steps, from 1 to N, used to deliver the learning content to achieve the learning objectives); (vii) Conclusion (a summary of the topic); (viii) Evaluation (contains some questions or class work to ascertain that the learners have understood the sub-topic and that the learning objectives have been achieved); (ix) Assignment (to be done after the class). Accordingly, the courseware tree that was used in the design of the learning content of the e-learning application consists of four levels: Course, Topic, Sub-Topic, and Learning Object.

However, beyond the lesson notes, it was necessary to prepare and use specifications (learning outcomes and contents) that ensure coverage of the approved syllabus and the recommended learning objective/outcomes. This involved understanding and using the subsisting West African Examination Council (WAEC) Mathematics syllabus/curriculum, and the subsisting standard Mathematics text for senior secondary schools (New General Mathematics Books 1-3).

A Learning Object (LO) is a self-contained chunk of learning content focused on a specific learning objective. It can obtain text, video, images, a flash animation, etc. Learning objects may be seen as building blocks that can be combined in nearly infinite ways to construct collections that might be called lessons, modules or courses. (Kilby, 2002). The essence of using LOs is to increase learning effectiveness, ensure compliance with instructional design standards, and reduce development time and costs drastically.

The lesson plans and notes of the participating mathematics teachers were discussed with them and used to understand the order of presentation of topics, sub-topics and learning objects in the traditional classroom approach. The understanding was then used to design an Input Courseware Presentation Order (ICPO) for each learning module and unit. This is shown below in Figure 2. Next, the implementation of the ICPO as a courseware involved developing output screens to match each step in the ICPO, and ensuring: (a) the module title is to be displayed prominently and be as descriptive as possible; (b) the total text of each module is between 100 and 300 words, with less considered better, provided there is an adequate accompanying voice narrative; (c) the use of illustrations, graphics, animation and activity; (d) the enabling interactivity

through drag and drop features, true/false statements, compare answers mechanisms, multiple choice quiz, etc.

Table 2: Steps/Screens in the Presentation of Learning Objects within Learning Module/ Unit

Step/Screen 1:	Present Title, Topic (and/or Subtopic)
Step/Screen 2:	Present Learning Objective
Step/Screen 3:	Present Concept/Idea. Provide its description.
Step/Screen 4:	Build on the description concept/idea presented
Step/Screen 5:	Provide example, and solution
Step/Screen 6:	Provide another example, and solution
Step/Screen 7:	Provide further optional examples and solutions of increasing difficulty
Step/Screen 8:	Provide Exercise 1, for Learner practice
Step/Screen 9:	Provide Exercise 2, to assess the Learner

Application Design

Architecture

The design of the *E-Maths* application adopted the basic three-tiered architecture, comprising the web client, web server and the database. The web client allows users to create, edit and access learning contents. The web server stores the script codes that provide links and communication between the application's interface and the database that stores the learning content.

Interface Design

The Welcome and Module Selection screen of the interface is as shown below in Figure 2. It incorporates an attractive, simple and easy-on-the-eye design. The colours used are bright colours. This is intentional, as teenagers (13 – 18 years) form the main age group of the senior secondary school students. Figures 3-5 provide snapshots of some of the screen sequences used for the delivery of the learning content and objects.

Application Development Tools and Processes

Figure 2(a): Welcome Screen

Figure 2(b): Module/topic selection page

Figure 3(a): Another expository page in the Latitude/ Longitude module

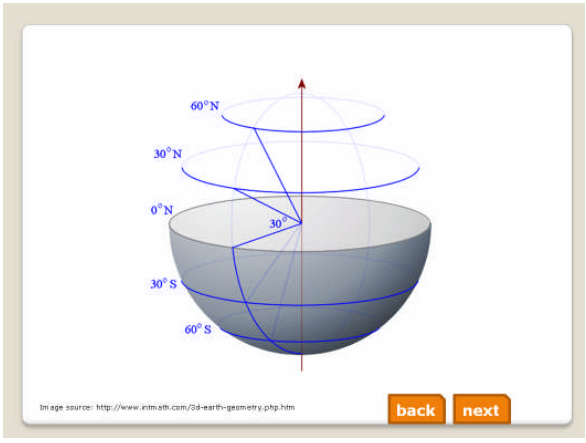

Figure 3(b): An expository page in the Latitude/ Longitude module

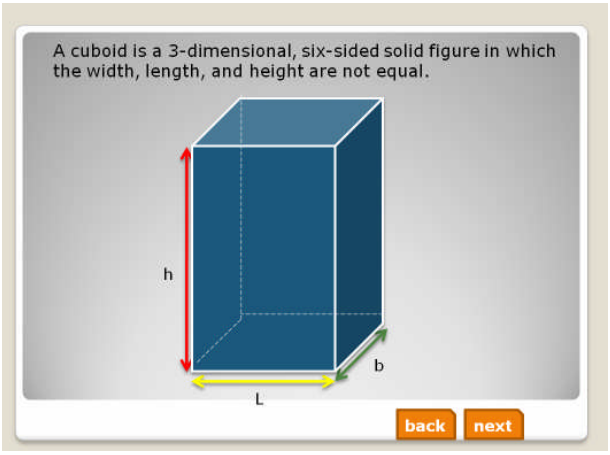

Figure 4(a): An animation in the Cuboids module

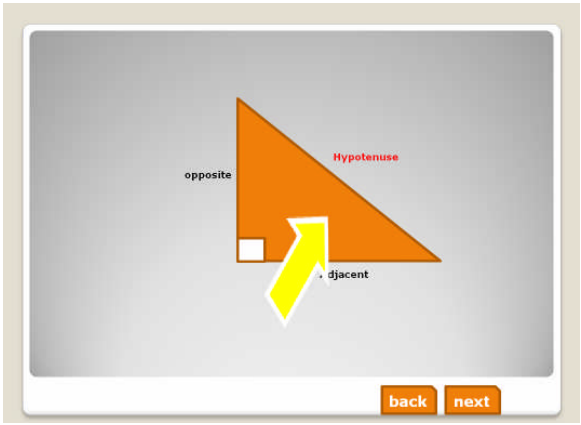

Figure 4(b): Animated sequence in progress in the Pythagoras' Theorem module

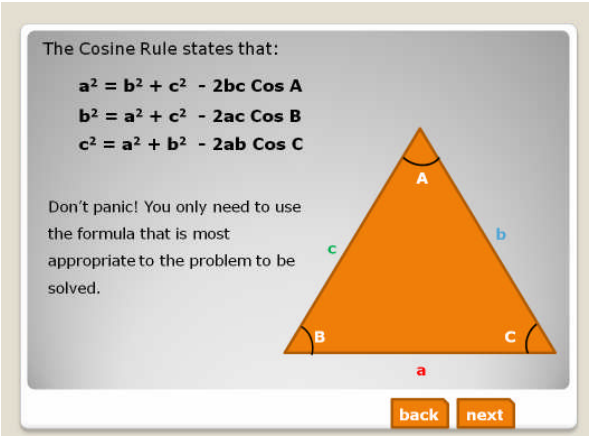

Figure 5(a): A sequence in the Cosine Rule module

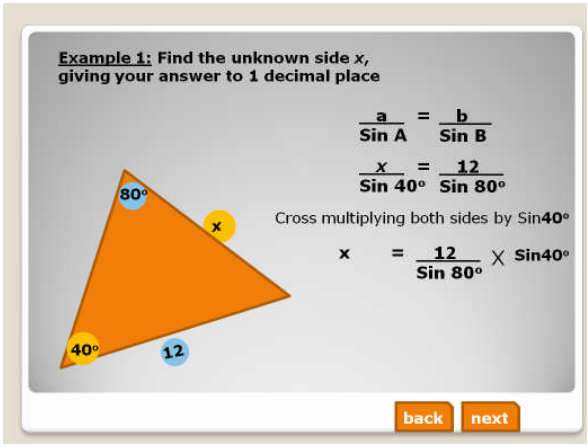

Figure 5(b): Animated sequence of an example in the Sine Rule module

Offline (CD-ROM based) and online (web-enabled) versions of *E-Maths* were developed. The hardware used is a laptop computer with the following configuration: Pentium M Intel Centrino dual core processor; 120GB of HDD; 1.0 GB RAM; 15.6" widescreen monitor; Mouse; Microsoft Windows 7 and Windows Vista operating systems; CD-Rewritable drive. The coding of the *E-Maths* application was initially started on a laptop running the Microsoft Windows Vista operating system (OS), and completed running the Microsoft Windows 7 OS.

Offline Version: The development of the offline CD-ROM version made use of the following tools: Adobe Flash (and Actionscript), Authorpoint, Articulate Presenter, Microsoft PowerPoint and Audacity tools. Adobe Flash (and ActionScript) was used to develop the assessment aspects of *E-Maths* (e-Learning tool). Also, due to its portability, reusability and the prevalent use of shockwave files (generated from Adobe Flash), this proved to be an important tool for cross-platform use. Authorpoint and Articulate Presenter are alternative rapid e-learning development tools used for converting files to the "swf" (shockwave or flash object) format. It accepts multimedia programming files as input. Microsoft PowerPoint was used, in conjunction with Adobe Flash, for the core multimedia programming requirements of the *E-Maths*. Audacity is an open source audio recording software that was used to capture, edit and embed sound files, and to convert into MP3 formats and other portable formats for use in the swf files obtained. The CD-ROM version of *E-Maths* entailed coding the data (courses and learning objects) into the program itself. The implication of this is that the offline version requires no login details, which would have required matching with data stored in a database. The user just plugs and plays the CD-ROM. The drawback, however, is that the learning objects in the CD-ROM version are read-only data that cannot be modified unless the CD-ROM version of the application itself is modified.

Online Version: An web-enabled version of *E-Maths* enables its deployment over a school LAN or the Internet. The development of the online version made use of PHP scripts, WAMP server, MySQL, and Drupal Content Management System. PHP, an acronym for Hypertext Preprocessor, was used to create dynamic web content, and to manipulate information held in the MySQL database. PHP code can be embedded in HTML or used in standalone applications. WAMP packages were installed on a computer running Microsoft Windows 7 operating system (O/S). WAMP is an acronym formed from the initials of the **W**indows O/S and its other principal components, **A**pache, **M**ySQL and **P**HP. WAMP is used during application development to create a web server environment on a PC. Apache is a web server, enabling a user on local host with a web browser to

be able to connect to view information from the web server as web pages. Drupal was used to create, build and manage the website. It is a robust, open source content management system.

System Evaluation

According to Nielsen (2000), the best results of usability testing come from testing with no more than five users but running as many small tests as one can afford, and that one needs to test with at least 15 users to discover all the usability problems in the design. A preliminary evaluation of the operational use of *E-Maths* was undertaken by three groups of 23 evaluators: 10 senior secondary school students (SSS) (aged 14-18 years, seven female) from a private secondary school; eight SSS Level 3 students (aged 1-18, five female) from a public secondary school; five teachers, all from Ibadan, Oyo State, Nigeria. The students and teachers were asked to use and assess the application and complete an evaluation questionnaire.

All the students from the private secondary school claimed to have had experience using computers. They all agreed that the layout of *E-Maths* was clear, and that the tool was easy to use, start and stop. They also reported that they found the tool easy to navigate, that the language understandable and the grammar accurate, and that the graphics, animation and accompanying audio sound were relevant, adequate and aided their understanding. They indicated that they liked the fact that the tool was easy to understand and an aid to topic comprehension, and was a time saver (each module took between 10-15 minutes to learn). They however expressed dissatisfaction that the audio was not loud enough, that time transition between pages was too fast which did not allow them to jot down ideas gained while learning the content. They felt the examples and exercises used were too simple, and suggested that more difficult examples and more topics (like surds, bearings, circle theorem, quadratic equations, angles of elevation and depression) be included.

Three male students and one of the five female students (among the eight students from the public school) claimed to have had experience using computers. The majority of them agreed that the layout of *E-Maths* was clear, and that the tool was easy to use, start and stop. They also reported that they found the interface easy to understand, with the graphics and animation relevant and aiding understanding. All of them were excited and impressed with the tool. They found it quite easy to understand and very relevant, and the diagrams quite explanatory. But they were also dissatisfied with the low sound output, and the speed of transiting from one page in the module to the next. They also wanted the solutions to the exercises to be more detailed and better expressed. They suggested that the audio quality and loudness be improved, with more detailed and well expressed solutions, and more topics covered (like probability, circle geometry, bearings and distances, etc).

The teachers (third group) were a bit elusive. They were either too 'busy' or wanted to give that impression. Their comments were constructive but with mixed reactions. *E-Maths* was called "highly commendable", clear and making for easy understanding and aiding visualisation. It should be noted that most students find mathematics difficult because they find it abstract and not easy to visualise. They suggested adapting/packaging it for viewing on the television via CD/VCD players, inclusion of more topics and more exercises and tougher examples and worked exercises, solutions steps written on the screen along with the audio explanations; inclusion more interactivity to reduce passive listening on the part of the students.

These are observations which are now being used to improve the content delivery quality of *E-Maths*.

System Deployment

E-Maths is designed to be deployed for use in versions: (1) Deployed and accessed directly from a CD-ROM. This is the preferred mode of delivery, as the majority of the secondary schools who are the intended users may have standalone computers but lack LAN facilities or Internet access. (2) Deployed and accessed from a server in an Intranet or the internet. This version enables *E-Maths* to be used in a WAMP environment.

Deployment Feasibility

Hofstrand and Holz-Clause (2009) define a feasibility

study succinctly as an analysis of the viability of an idea. It helps the designer to accurately assess the probability of the success of the new system. The feasibility study was done during the system analysis that preceded the design and development of *E-Maths*, and after its development.

Technical and Operational Feasibility: The system analysis revealed that most public secondary schools do have available at least a set of computer systems, though this might be locked up inside the Principal's office. A school that one of the researchers investigated even had a VSAT installed in the school premises. Another school in which the researcher acted as a volunteer mathematics teacher had a set of computers donated to the school by the Parents Teachers Association. Recently, teachers in Oyo State were directed by the government to be computer literate. Thus, the government is encouraging the use of information technology tools by teachers and students. In the same vein, university graduates from the National Youth Service Corps scheme (who are expected to be computer literate) are posted to these public schools. Furthermore, most of the senior secondary school students, particularly in the uppermost class (SS3), possess basic computer literacy and skills for operating sophisticated mobile sets and using computer chat or browse the Internet, register for public examinations online, or access their Facebook or Twitter accounts. Access to computers is also readily available, for instance at cybercafés located at various points in urban areas, near schools, and in some rural communities. Both the online and CD-ROM versions are therefore technically and operationally feasible for secondary school teachers and students to use.

Economic Feasibility: Economic feasibility relates to the financial resources needed, not only to deploy and maintain a new system. The major additional expenses to be considered by a school that wishes to use an e-learning system such as *E-Maths* are: (i) acquiring, installing and maintaining desktop computers for students' use; plus (ii) establishing a school intranet to run the online version; or (iii) acquiring the CD-ROM version for offline use by students within the school or at home. The CD-ROM version clearly has almost negligible cost implications compared to the intranet option, particularly if the school already has some computers for students use.

Hardware, Software and User Training Requirements

In terms of the hardware and software requirements to use *E-Maths*, these were determined carefully, taking into consideration the fact that the students are likely to use it in environments (public secondary schools or homes) where only very basic desktop systems are available and local area networks (LANs) are absent. Thus, the application is designed to run on Microsoft Windows 98 (and preferably Microsoft Windows XP or later versions), with installed flash player and web browser (preferably Mozilla). The following minimum level hardware configuration is recommended: 512Mb RAM; 40Gb HDD; 52X CD-ROM drive; 15" SVGA monitor; Pentium III processor; Multimedia kit.

In respect of user skills and training, at the very least, it is assumed that users of *E-Maths* have basic skills in computer operations. Therefore, the training required is to expose users to the basic operations of the tool. A computer appreciation course can be organised for all teaching and administrative staff. Students may be included, although the system analysis revealed that most of them at the SSS level have adequate computer skills to use the CD-ROM version. However, for the effective use of the online version, the required training content should cover: computer fundamentals; windows fundamentals; applications packages (especially Microsoft PowerPoint and AuthorPoint); and hardware and software management. In addition, for the deployment and administration of the online version of *E-Maths*, some selected teaching and technical support staff might need basic level training in the use of PHP, MySQL, Acquia Drupal packages and the WAMP environment.

Recommendations

Based on the findings obtained in the different aspects of the work, from literature review, through system analysis, design, implementation and evaluation, it is recommended that:

(a) Computer skills should be taught in all public secondary schools.

(b) School authorities, backed by governments and the federal and state levels, and private sector organisations should make available computer systems and backup electricity power supply sources to public schools.

(c) Teachers should be availed the opportunity to acquire computing and participatory e-learning development skills through short holiday courses.

(d) Teacher training institutions should include the development and use of e-learning tools in their curricula.

(e) In view of the ICT infrastructural constraints that most Nigerian secondary schools face, hybrid forms of e-learning that combine face-to-face classroom instruction delivery and e-Learning using CD-ROMs as a delivery platform is the most practicable option available for some time, although an intranet-based learning management system could also be deployed in some schools.

Conclusion

Among other things, this research has shown that the e-learning tool development process is not rocket science, neither is it the exclusive domain of computer scientists or programmers. A knowledgeable and experienced classroom teacher armed with knowledge of computer operations could use available content management tools to do it. Due to the limitations of time, this research limited itself to only a subset of mensuration topics in the existing WAEC mathematics syllabus. Further research could focus on: comprehensive testing and use evaluation across many schools of the initial and improved versions of *E-Maths*; experimental testing of the application to assess impact on students' achievement in mathematics; coverage of more topics from the mathematics syllabus; coverage of other subjects in the secondary school curriculum; a collaborative effort among schools to develop other e-learning tools, approaches and courseware for use in the various Nigerian public and private secondary schools.

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