Development of an E-Learning Architecture Based on Numerical Computing Software for Electrical Engineering Education in Open and Distance Mode

I.A. Premaratne
The Open University of Sri Lanka
iapre@ou.ac.lk

Abstract:
In this paper an e-Learning architecture is proposed which is based on Octave software to use in Electrical Engineering education. It is always challenging to interpret physical meaning of a concept only by teaching in a classroom environment. Therefore all engineering courses recommend and include laboratory exercises in the curriculum to verify theories which are taught by printed lesson materials or lectures. These kind of laboratory activities can be performed only in a laboratory environment hence it is difficult for students to learn at their own pace or time. Where Electrical Engineering courses offered in open and distance mode it is more difficult to find time for students to engage in laboratory activities. As an alternative, interactive eLearning materials have been introduced for open and distance mode. Although the interactive materials can provide an effective learning experience to students, it is not a straightforward option for educators as it requires more computer programing knowledge and additional time to setup the tools. This research is focused on developing an eLearning architecture which requires less computer programming knowledge than existing methods. For this method, Octave software has been used as the platform which provides opportunity of distributing both the platform and the eLearning material with an open license. The material developed on this platform is self-instructional and capable of running at user desired time and pace which would provide flexible learning. As the platform supports text, calculations and graphing on same workspace, the material could cater all learning styles. Learning outcomes are aligned constructively according to the Structure of Observed Learning Outcomes (SOLO) taxonomy. The material was tested allowing learners to attempt self-assessment questions. Results are analyzed to grade the overall achievement of learning outcomes.

Introduction

As the concept of openness in education is widely promoted and encouraged all over the world, the distance mode education achieved a significant stage nowadays. The research done by (Nyathi, Talarico, Rodriguez-Marek, & Koh, 2011) shows that, most countries including United States of America establish institutes and universities to promote distance education. The distance education supports the people who have missed the conventional university or high school education due to reasons such as personal matters and lack of facilities. It can also provide opportunities for the employed people in the industry to obtain qualifications in their relevant field. Likewise, people can advance along the career progression by continuing education with the help of distance education. This research has been conducted on electrical engineering education in distance mode of delivery. As presented by (Marasco & Behjat, 2013) creativity should be integrated especially in elementary electrical engineering education in order to increase the quality of graduates in the field. Since most engineering degree programs have creativity as a program outcome, it is required to integrate learning outcomes at course level and session level to meet the requirement. The research conducted by (Nasrallah, 2014) shows the Structure of Learning Outcomes (SOLO) taxonomy is preferred over Bloom's taxonomy to be practiced in higher education.

Problem of Electrical Engineering education at a distance

The Electrical engineering is one of the foundation platforms which support the continuation of Electronics, Telecommunications, Electrical Power and Computer disciplines of engineering. Therefore the students, who are willing to follow the aforementioned study areas, have to undergo Electrical engineering fundamentals in their first year of study at the university. In the first year the syllabi are designed to cater the common topics to Electronics, Telecommunications, Electrical Power and Computer engineering. As studied by (Ribickis, Kunicina, Zhiravecka, Chaiko, & Patlins, 2010) the electrical engineering education needs more research based approach in learning compared to social sciences and arts. They have shown that it should have adequate laboratory based practical learning in order to grasp the theories thoroughly. The reason is Electrical engineering has applications which are always to control physical equipment and phenomena. The need of information tools to engineering curriculum is a key fact in education. This fact is clearly identified and presented by (Patlins, Kunicina, & Ribickis, 2011). The increase of student number in a particular program again reduces the opportunities per student to use laboratory instruments. As (wa Maina, Muhia, & Opondo, 2016) has shown in their study, the essential experiments can be done by using low cost lab tools. Although the cost is reduced, there should be an architecture to deliver the contents of the course. In some cases certain theories should be taught by visualizing the conceptual facts such as Fourier analysis of signals and systems and Laplace transform of systems. The study conducted by (Vandewalle, 2011) shows how challenging the teaching of electrical circuits and systems using only printed material.

The main challenge of teaching electrical engineering at a distance is conducting practicals at a distance. This problem is unavoidable since the practical experiments should be done at a dedicated laboratory and under proper supervision of competent person. Therefore students have to attend the laboratory at the institution. It is evident that electrical engineering education is difficult to deliver completely in distance mode. However the learners can attempt on pre-lab sessions which are delivered online as e-learning workshops. This technology is presented and tested by (Apse-Apsitis, Avotins, Krievs, & Ribickis, 2012) to address the issue of having less number of hours at the laboratory. The research done by (Peteris, Ansis, & Leonids, 2012) also suggests the remote workshop using online learning.

Many education researchers have worked on finding alternatives to laboratory activities such as proving virtual laboratory environments based on eLearning architectures. The survey done by (Cao & Zhu, 2010) shows how iEELab hybrid lab model - a network connected hybrid lab – can be used for electrical engineering education. It connects the physical instruments to a web based network which allow the users to operate them at a distance. Although the system provides adequate results to the problem, this kind of instruments and the infrastructure is expensive in the market. Another virtual lab has been introduced by (Valdez, Ferreira, Martins, & Barbosa, 2014) in their study on VEMA labs. It does not have any physical instrument. Instead it contains only virtual instruments. Students can use the instruments as they supposed to do at the laboratory and conduct the experiments. It is again a system which requires online connectivity to perform the activities. The importance of visualization of physical models such as electrical rotating machines, high voltage instruments and electrical measuring instruments is clearly explained by (Stockrahm, Kangas, & Kotiuga, 2016) in their study. It concludes that in electrical engineering education the learner should have the idea of how theory would apply in physical systems.

As the information technology advanced, platforms were developed for online course delivery especially to be used with smart phones and tablet computers. As presented by (Goebel, Siemund, & Kracht, 2016) the S.m.i.L.E technology developed in Germany, provided opportunities for learners to use their smart phones and tablet computers to read the lesson materials. Since the materials are web based it contains graphics and animation as learning aids. The research done by (Enache, Vlad, Campeanu, & Enache, 2014) also shows the use of online web based computer tools in electrical engineering education which require graphic designing knowledge to develop the material.

The Study

As shown in the introduction section of this paper, use of information and communications technology (ICT) can contribute to laboratory based learning in electrical engineering. The research done by (Belagra, Benachaiba, & Guemid, 2012) defines the ICT in education as use of technology to transmit, store, create, share or exchange information. Therefore it includes learning through text book, multimedia and interactive modes. The researchers (Porebska & Wantuch, 2015) compare the role of computer supported tools in electrical engineering education with the traditional learning environment. It is observed that there is a need of interactivity in learning material.

Affordance of open source software

The results provided by (Žáková, 2015) shows that most interactive tools are available as commercial software such as MATLAB and LabView. The research conducted by (Pavani, 2011) has presented the importance of integrating open courseware, open access journal and other open education resources to enhance electrical engineering education. Therefore in this research, it was focused on searching an open source software to be used as the platform for e-Learning architecture.

The most widely used numerical computing software for both engineering applications and engineering education is MATLAB which comes with a proprietary license. Since the price of an individual license is very high, the availability of MATLAB for educational purposes is very low in developing countries. The open source alternative to MATLAB is considered as OCTAVE. Both products have same architecture with certain limitations. Since MATLAB software is designed especially for industrial purposes, it is required to examine whether in which way it can be used as an educational aid.

The research done by (A.P. Leros, 2010) clearly concludes that both OCTAVE and MATLAB are suitable for electrical engineering education purposes. It shows the circuit simplification techniques, control systems simulations and graphing of variables are equally illustrated by both Octave and MATLAB. Therefore in this research OCATAVE has been used as the numerical computing software to develop the lesson material.

Proposed Architecture

From the facts given in the introduction section of this paper, in order to overcome the issues arise when teaching electrical engineering at a distance, there should be ICT tools integrated in the courseware. Also these tools should have interactivity from the learner's perspective and also user friendly developing method from the teacher's perspective. Therefore a new e-Learning architecture has been proposed to use same software platform by both teacher and learner. Figure 1 shows the block diagram of the proposed architecture. Since Octave comes with GNU general public license, it can be freely redistributed from the university to the learner. As shown in Figure 1 the first developer of the material is Teacher 1 who has adequate knowledge in handling program codes on Octave.

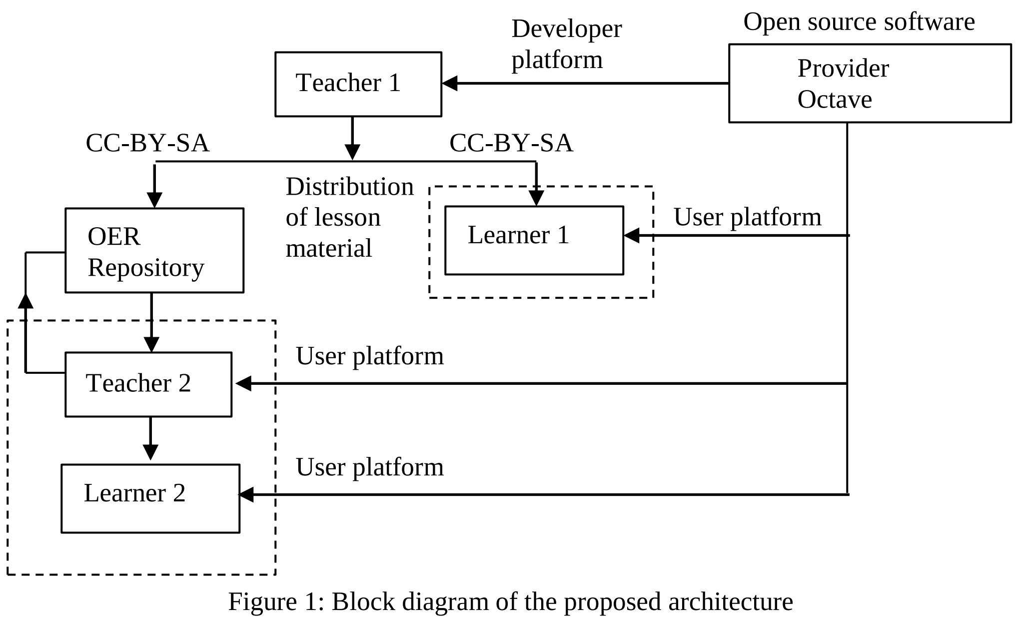

Figure 1: Block diagram of the proposed architecture

The lesson material in this architecture is a file with the extension .m which is the executable file format for both MATLAB and Octave. It can be edited using the software editor or using any form of text editor available in the operating system. In this architecture the file is produced for both teachers and learners. Teacher 1 develops the material and share the learner version directly with the learners. The teacher version of the file contains instructions to the teacher which should be erased when giving to the learner. It can be made available to the public by sharing to an OER repository. Learner version has the instruction to follow when using the material. Same software is used as the material developer platform and the material user or the learner platform. All redistributions of the material would be OER in Creative Commons attribution - share alike license. The teacher 2 who may or may not be an expert in Octave programing can revise the material and provide it to learner 2. Modifications to the material can be done by teacher 2 with the teacher instructions given in the material.

Testing of the architecture

In order to develop eLearning materials, it was required to select a particular area of basic electrical engineering. When selecting, priority has been given for topics that most students are reluctant to study and attempt answering questions at assessments and tests. As identified by (Vandewalle, 2011), the concept of complex power in alternating current (AC) circuits is one of the difficult sections for first year students. When the students are registering for the first year electrical engineering courses they are familiar with direct current circuits because they have studied those topics at secondary school. When studying alternating current circuits the students are supposed to combine voltage and current relationship with complex number format which they are very reluctant to perform. From the students point of view it is acceptable that when something in the text book is not reflecting in reality. In text books the relationship between voltage and current is given as a mathematical formula always. In reality this can be shown using the oscilloscope with simple set of circuit components. The problem is the oscilloscope can be used only at the laboratory. Therefore when the students are reading a course material they would not get the opportunity to use the oscilloscope right at the moment. From this point we could start to develop e-Learning materials to support the student to learn by both reading and doing. By considering above facts, a lesson of a first year electrical engineering course has been selected. The details of the selected lesson are given in Table 1.

Table 1: Details of the selected lesson for the development of material

Program of study	Bachelor of Technology (Hons) Engineering, The Open University of Sri Lanka
Course title and code	Electro Techniques ECX3210
Course description	First year core type common course for Electrical, Electronic and Communications and Computer Engineering
Lesson	AC Theory
Topic	Power in AC circuits. Active, Reactive and Apparent Power
Relevant course outcome	Analyze AC electric circuits using basic theories

As mentioned in introduction section of this paper and the research conducted by (Bhattacharyya, Bhattacharya, & Mitra, 2012) the learning outcome development has been done according to SOLO taxonomy. Based on the results of the research conducted by (Biggs, 1979) it was considered the course outcome is at multi-structural level which the knowledge is constructed from several independent aspects. In order to construct the expected knowledge level, the outcomes have been developed for the proposed learning material. The outcomes are,

1. Identify the instantaneous power of an AC circuit.
2. Identify the phase angle difference between voltage and current of an AC circuit.
3. Explain the change of useful power in the circuit with the variation of phase shift between voltage and current.
4. Explain the existence of reactive power in an AC circuit.
5. Describe the interpretation of complex power and apparent power by means of complex numbers.

In the designed material, the instructions are given in text format. It guides the learner to define the voltage and current waveforms in Octave workspace. Then it is providing the opportunity to the learner to change the phase difference between voltage and current by changing the parameters of the codes given earlier. The material is designed so as to generate the graphs of the waveforms in the same workspace. Then the learners can visualize the behavior of waveforms. The interactivity is made available at this stage where the learner can input values as they wish and observe the changes. Since the calculation formulae is also given in the same material they could verify the theoretical knowledge with the results. The progression of the material is designed to construct the knowledge by satisfying each learning outcome. The learner can repeat the process until they acquire the knowledge.

Findings

In order to test the developed material a sample of ten volunteered students who are following Electrical Power, Electronic and Communications and Computer Engineering specializations at the Open University of Sri Lanka has been selected.

All participants were given the learning material and allowed to spend around five hours to complete the lesson. Since the material itself acts as a self-assessment the participants were asked to complete an online questionnaire developed using Socrative Quiz. The online quiz was opened for a fixed duration and the questions were asked one at a time. From the options available in service provider it was selected the teacher pace option. It was to get the learners feedback for each question without spending too much time. It is assumed that taking too much time will deviate the originality of the learner feedback. All responses were recorded as anonymous users to protect the privacy of participants.

The questionnaire consisted of ten questions. First three questions were to test the overall likeness and the interest of the learners which are multi choice type. As presented by (Boulton-Lewis, 1994) the high school students are able to test their own outcomes by self-assessment. Therefore question four to eight were designed as short answer type and briefly assessed the learning outcomes of the material. Those questions were measuring the level of construction of knowledge in instantaneous power, phase difference between voltage and current, relationship between phase difference and useful power, reactive power and the complex power of AC circuits respectively. Last two questions are again multi choice type and testing the likelihood of sharing the material with peers.

The results of the online questionnaire has been analyzed. According to the results, all participant have gone through the entire material for at least two times. The answers given for question four to eight have been summarized since each individual have given answers in different styles. Table 2 presents the overall aspects of participants. The expected level of understanding is given in the third column. The definitions for each concept is formulated based on the explanation given by (International Electrotechnical Commission, 2016).

Table 2: Summary of results of achieving outcomes

Concept	Learner aspects (outcomes) summary	Expected knowledge
Instantaneous power	Multiplication of instance value of voltage and current	Product of voltage and current
Phase difference	Delay of current to voltage	Displacement of current to voltage
Useful power	Average of the power waveform	Mean value taken over one period of power
Reactive power	Power does not come out of the circuit	Imaginary part of power
Complex power	Sum of active and reactive power as a complex number	Sum of active and reactive power

By analyzing the results, it is observed that the learners have found the meaning of given terms to the expected level. More importantly the concept of reactive power is interpreted by learners with clear physical meaning. From the results of last two questions, it is found that all participants are willing to share the material with their peers as they think the peers would also enjoy the learning environment.

Conclusions

Electrical engineering education requires hands on experience in order to make students more interested in studying. As identified in the introduction section of this paper the problem is, providing more learning hours for laboratory experiments at the institution. The solution proposed in this research is to use a new e-learning architecture which can be developed and used on open source numerical computing software. The main objective was to provide more opportunities for teachers and learners to develop and use the material as they are provided with open license. The testing of example material has provided results to conclude that the new architecture can increase the interest of students to engage in self-explanatory studies in electrical engineering. Since the self-assessment is also a part of interactive material the students are encouraged to test their own knowledge and repeat the process until they are satisfied with the achievement. Since the Octave codes used in this material development were in the form of mathematical functions and basic program branching, it did not require deep programing knowledge of teachers. Therefore we conclude that the e-Learning architecture based on Octave software could be used in electrical engineering education for the enhancement of open and distance education.

The architecture will be tested for more topics in the field of electrical engineering in future. As an advancement of the research, the graphical user interface features of Octave will be tested to be integrated to the lesson material. By using this feature it is expected to increase the interactivity of materials.

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