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Effective Incorporation of E-learning Features in a Foundation Engineering Course

Dipti Srinivasan

Department of Electrical & Computer Engineering, National University of Singapore, 4 Engineering Drive 3, Singapore 117583

dipti@nus.edu.sg

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Abstract

Conducting a foundation level university engineering course poses several challenges due to large enrolments and varying background of students. Classes are typically large, and conducted in lecture theatres thus limiting the amount of interaction and discussion among the students and with the lecturer, and lack of flexibility in class activities. This paper presents an e-learning approach that was implemented in teaching a first year electrical engineering course with an average class size of 450, and incorporated extensive use of web-based activities, videos and animations for explaining fundamental principles using examples, scenarios and practical applications that students could relate to. These components complemented the regular lectures and tutorials, and enabled the students more flexibility in learning and understanding the topics covered. Student feedback data obtained over eight consecutive semesters showed that students found the overall learning process to be more effective and enjoyable, and displayed better understanding of course content as demonstrated through various assessment tasks.

Keywords

E-learning; Large Classes; Foundation Courses

Introduction

The primary focus of engineering education has shifted from just imparting engineering knowledge to students in the past, to institutionalizing a coherent mechanism for providing a broad understanding of various technologies, creation of new technologies, and nurturing the ability to apply them for the benefit of humankind.

Engineering educators strive to build a sound foundation in engineering fundamentals, cultivate critical thinking, and develop strong problem solving skills among their students so that the students can apply their knowledge to new contexts and practical problems. The first year of the curriculum emphasizes developing a strong foundation in mathematics, physical science as well as, introduction to various engineering disciplines, while in the remaining three years, students focus on the subjects that form the core of their engineering program and complete a senior design project as part of the graduation requirements. First year engineering courses are therefore crucial as this is where a student gets his first taste of the subject and decides whether or not to pursue a bachelor's degree in that field of engineering.

Several research works on higher education teaching and learning recognise motivation as an essential prerequisite for successful learning in large classes. The ability to maintain and enhance student's motivation, regular interactions with the faculty, individual attention, and variety of teaching-learning activities are some of the most important factors that have been identified. However, one challenge that is unique to foundation level university engineering courses is maintaining the quality of student learning in the face of rising class sizes. A review of the literature [Cuseo, 2006; Iaria, 2008; Kokkenlenberg, 2008; Atkinson, 2010; Bedard, 2008; Bezuidenhout, 2009] shows that as the number of students increases, not only does their motivation and active involvement in the learning process decrease but also the assessment tasks show reduced development of cognitive skills inside the classroom.

A literature review of current best practices [Arias, 2004; Entwistle, 2010; Biggs, 1999; Cooper, 2000; Mulryan, 2010; Revell, 2009; Robinson, 1986; Deslauriers, 2011] adopted in the teaching of large classes and the strategies that were adopted to address the issues mentioned above indicates that the critical factor was not the number of students, rather how well the good teaching principles were implemented and course was managed. The research also highlights that, large classes, if managed and conducted well, provide unique opportunities for positive teaching and learning experiences, and exploring multiple perspectives on course content. Engineering educators have, in recent years, started to exploit the power of technology and experimented with several blended learning formats using an amalgamation of face-to-face learning in the form of lectures and tutorials, and varying levels of technology to enhance student learning. Many studies in the field of engineering education have shown effectiveness of videos, animations and other media resources to enhance the learning experience [Rehg, 1996; Director, 1995]. The increasing availability of such resources has presented educators with the opportunity to relook at the entire teaching and learning process and investigate the applicability of new delivery methods [Whitman, 2004; Paulo, 2012; McMenemy, 2009]. Several such studies have shown the effectiveness of these initiatives in enhancing the teaching and learning process. Recent works have also shown great promise of e-learning methods using video and interactive web-based activities [Fraile, 2009; Nestor, 2008; Wong, 2006; Drozdova, 2007].

This paper illustrates how several e-learning features were effectively incorporated in teaching an electrical engineering foundation course that all freshmen engineering students are expected to take in their first semester of study. The cohort typically comprises students with diverse backgrounds from several Asian countries. This course introduces basic concepts in electrical and computer engineering in an integrated manner, and motivates the understanding of these concepts in the context of practical engineering applications. The basic understanding achieved in this course forms the foundation for subsequent study in electrical engineering. The course content was designed such that new material was integrated with students' prior academic experiences to make the overall curriculum more comprehensive and less fragmented. Many e-learning features such as videos and animations for explaining important concepts and principles, as well as, web-based tutorials, examples, scenarios and practical applications were incorporated so that students had ample opportunities to learn at their own pace. This learner-centered approach helped the lecturers share useful resources, and encouraged sharing problem solving and learning to augment face-to-face interactions. Student feedback data obtained over eight consecutive semesters showed that students found the overall learning process more effective and enjoyable, and displayed better understanding of course content as demonstrated through various assessment tasks.

The rest of the paper is organized as follows. The next Section presents the details about the course used for this case study, after which the various e-learning features and examples are presented. The evidence of effectiveness of these e-learning initiatives is presented next, following which the main conclusions are highlighted.

Course Objectives and Description

The course selected for this case study is a first year course which aims to introduce basic concepts in electrical and computer engineering in an integrated manner, and motivate their understanding in the context of practical engineering applications. It covers the basic understanding of various electrical engineering areas that address the high-technology needs of the modern society and include analog and digital circuits, power electronics, control systems, circuit theory, computer architecture, and electrical energy conversion devices. The topics covered are: Kirchhoff's Current and Voltage Laws, Ohm's law, ideal and real sources, ac circuits, power, power factor, resonance, energy storage elements: capacitors and inductors, introduction to circuit concepts including diodes, operational amplifiers, transformers, dc machines and logic gates using applications. It is hoped that an overview of this major would introduce the students to the exciting world of electrical engineering that offers exciting careers within the varied electrical engineering and allied disciplines. Since the ability to design is an essential part of electrical engineering, students are presented with challenging and interesting design problems as part of the course. Laboratory experiments are an integral part of this course, and provide hands-on experience to strengthen students’ applied knowledge.

The course is designed to provide a greater sense of the breadth, capabilities, and usefulness of electrical engineering to all engineering students, but the treatment of individual topics is less vigorous than might be covered in a typical first course for just electrical engineers. The annual enrolment for this course ranges between 800 and 1200 students, and the average class size is 450.

The course outcomes for this course are as follows. At the end of this course students should -

a) be able to solve AC and DC circuits in steady state using Kirchoffs laws.

b) be able to generate Thevenin and Norton equivalent circuits for independent and dependent sources.

c) be able to apply maximum power transfer principle and superposition theorem to linear circuits.

d) be able to analyse AC circuits in steady state using complex phasors, and understand and demonstrate the concept of average, root mean square value, peak value in AC circuits

e) be able to understand the working of transformers and coupled inductors and use equivalent circuits for AC circuit analysis.

f) understand the basic characteristics of diodes and their use in rectifier circuits.

g) be able to understand and work with an equivalent circuit of a DC motor and the relationships between voltage, current, speed and torque.

h) have a basic understanding of gain, input impedance and output impedance in amplifier circuits using operational amplifiers.

i) have a basic understanding of digital logic, basic logic gates and use of Boolean algebra.

The subject is dealt with in a theoretical and analytical manner, yet ties in with many of the more practical applications that students are familiar with from their daily experiences. The continuous assessment tools include two mid-term tests and three laboratory experiments which make up 45% of the final marks for this course, while the final examination carries 55% weightage.

This course is conducted over 13 teaching weeks that provide 39 contact hours that include lectures and tutorials. In addition, the students attend three compulsory lab sessions to reinforce the concepts learnt and gain relevant hands-on experience. Additional “optional” exercises have also been developed for students who wish to engage in self exploration on topics related to these experiments. The e-portal created for this course contains all instructional material including lecture notes, tutorials, web-based assessments, animations and interactive tutorials. The assignments and tutorials include a mix of problems: routine problems to build the students' confidence; and difficult problems to challenge even the brightest. Though some students would rather plug numbers into formulas or follow procedures by rote, the tutorial problems were designed to encourage them to think for themselves.

In teaching this course, the main goal is to enable the students to develop a conceptual intuition. The students are encouraged to interpret new equations not as black-box formulas into which one plugs data and from which the answer appears. An attempt is made to present mathematical equations as a formal way of quantifying the relationships between physical properties, which helps them internalize the information. Efforts are made to achieve an conceptual intuition by starting with a simple system and working towards the more complex one. Thus, by starting with a concept that is already intuitive, more complex pieces are introduced, while staying focused on the fundamental premise.

E-Learning Portal

Since this course involves a rather large number of diverse topics to be covered in a limited number of contact hours, it makes extensive use of technology to introduce and reinforce concepts, teach analytical tools, and show their practical applications. A set of interactive computer-based courseware has been implemented to enhance the learning environment for students exploring electrical engineering. The objective is to facilitate learning by engaging students in course material through stand-alone learning modules emphasizing basic concepts with the help of animations, and to promote the development of self-efficacy among the students through the use of web-based tutorials designed to enable students to learn in a flexible, interactive manner. The courseware has been designed to manage course information in a structured and efficient manner, and provides the benefits of centrally-accessible resources and shared information for class management. The webcast of lectures is available so that students can view it to revise the topics covered. For enhancing the learning environment, self-paced learning units have been developed for foundation topics for the benefit of students coming from diverse backgrounds and to accommodate their diverse learning styles.

Each topic on the e-learning portal is presented as a learning unit, and has the following components:

Objective: This part focuses on why the topic has been included, and keeps everyone focused on goals and expectations of the learning unit.

Background Information: This section provides some fundamental concepts that introduce background knowledge to help the student in the learning process. Background information from previously studied math and physics courses provides the context and details and helps maintain a better focus on the topics developed within the learning unit.

Prerequisites: This part explains requirements needed before starting the topic, and includes necessary prior knowledge and specific skills.

Unit Structure: This outlines the main components and sub-topics and/or phases of the unit. The intent of this section is to explain how the unit is organized and what sub-topics are included.

Learning modes: The various learning modes for each unit, such as, the available videos, animations for learning concepts, self-assessments, self-learning tutorials, etc are indicated, so that the student can select the desired option.

Class Schedule: This part includes the schedule of lectures, tutorials, and labs for each topic.

The e-learning portal allows the students to understand difficult concepts through animations and explanations. Animations are used in many ways for illustrating basic concepts and to make the courseware come alive. The main objective is to minimize the time taken to learn and to maximize the learning experience. Numerous three dimensional animations illustrate the concepts in electrical systems, such as filter circuits and resonance, basic concepts in magnetics, transformers, motors, and operation of large-scale electrical energy systems, and have been successfully employed during lectures. Some of the files are also available on the web to allow the students to view the animations on an individual basis. These efforts have considerably enriched the understanding of some basic electrical engineering topics by the students.

A challenge in teaching this course has been the wide range of topics that are covered. Although explaining network theorems is rather straight forward, and is made easier with the help of excellent textbooks available on these topics, some of the other topics pose specific challenges. In order to help students develop a better understanding of the various application areas of electrical engineering covered in this course, several e-learning tools have been developed. In this e-learning portal, each topic is introduced via some examples and investigations, so that the students can click on the boxes to explore more on each topic. Flash-based animations allow the students to understand the underlying physical processes in a visual manner.

For example, this course aims to give the students an overview of some of the important fields in electrical engineering that are considered relevant and useful for all engineers. As a result, each lecture in this part is on a different topic. After the first 12 hours teaching basic circuit theorems, the second half of the course is an overview of several other topics. In this second half, the first lecture is on logic circuits, which form the foundation of all computers and digital systems. The second lecture is in the field of electrical energy systems, with a focus on transformers, which are extensively used in large-scale power systems, as well as, in small power supplies for domestic applications. The third topic covers rectifiers and power supplies, while the fourth lecture is on DC motors, which find wide-spread application in the industry. The last two lectures cover sensors, and instrumentation and measurement systems and include applications in various engineering fields. This topic also covers operational amplifiers, and some basic types of instrumentation systems which are extensively used in all fields of engineering. A solid foundation in electric circuits is essential for understating these topics. Knowledge of several basic concepts in physics is also required. The following examples illustrate the components of the e-learning portal.

Example 1: Electrical Engineering Systems in a Modern Automobile

Many of the seemingly different electrical engineering systems can be found in a very common application – the automobile. To show the relevance of various topics covered in the course to real life applications, such simple every day examples are used (Fig. 1). A modern car typically has an electric power system, several electric machines (generator and motors), sophisticated computer systems, many control systems, thousands of electronic components, and several measurement and instrumentation systems, all the topics that are briefly covered in this course. The students can click on a box in the picture to learn more about the electrical engineering system that he/she is interested to learn more about.

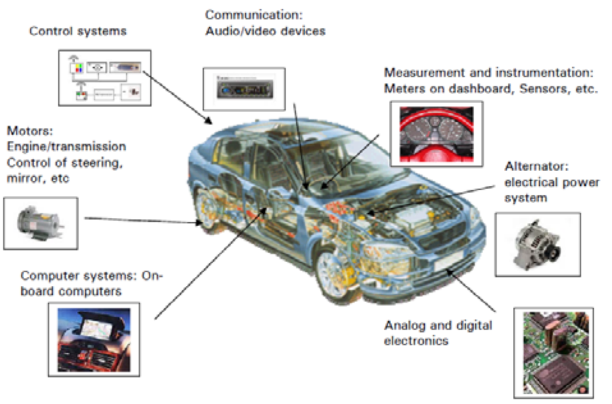

FIG 1: ELECTRICAL ENGINEERING SYSTEMS IN A MODERN AUTOMOBILE

Example 2: Transformers and Their Applications

To illustrate the operation and functioning of a transformer, its application in electrical energy distribution systems is used, and from this application example, the functions and connectedness of various components in the process are discussed. AC electricity is generated in power stations at medium voltage levels (*i.e.*, something like 11kV), and is consumed by the domestic user at an RMS voltage of 220V (in Singapore). The electricity generated at the power station is fed into a step-up transformer which boosts its peak voltage from a few kilo volts to many tens of kilovolts. The output from the step-up transformer is fed into a high tension transmission line, which typically transports the electricity over many tens of kilometers, and, once the electricity has reached its point of consumption, it is fed through a series of step-down transformers until, by the time it emerges from a domestic plug, its RMS voltage is only 220V. In the e-learning portal, this process is first presented using the actual system, and then a simplified block diagram as shown in Fig. 2. Upon clicking on the transformer icon, the student can then learn about the transformer.

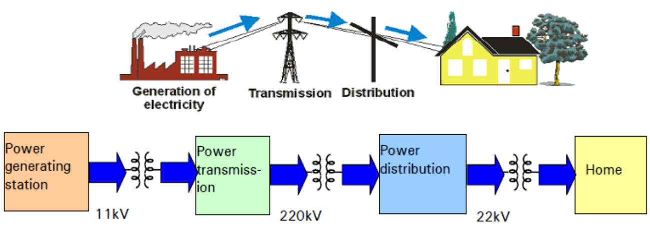

FIG. 2: TRANSFORMERS RAISE/LOWER VOLTAGES IN ELECTRICAL ENERGY DISTRIBUTION

Other common applications of transformers are in power supplies and for impedance matching in communication and audio networks. The e-learning portal presents the graphic representation of these devices, and through these examples, presents the difficult concept of impedance matching using the notion of "reflected load" (Fig. 3). The students are taught that using maximum power transfer theorem, the power source can be made to deliver maximum power to the load when a transformer is connected in-between them to match the two resistances.

The student can further explore this concept of impedance matching through self-learning tutorials and examples available on the e-learning portal. An example is shown in Fig. 4 below where the student can enter values for the internal resistance of the audio amplifier connected to a speaker, and determine the required turns ratio of the transformer such that maximum power can be delivered to the speaker.

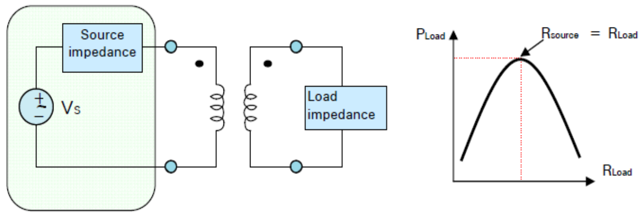

FIG. 3: TRANSFORMER APPLICATION FOR IMPEDANCE MATCHING

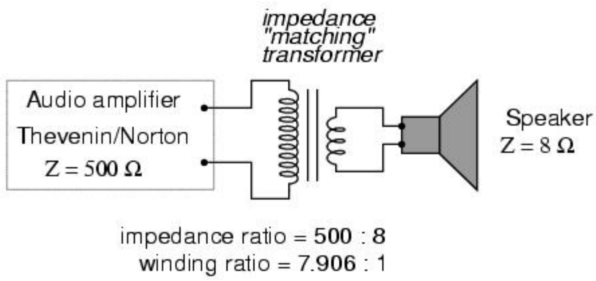

FIG. 4 TRANSFORMER CALCULATIONS

Example 3: Sensors and Instrumentation Systems

For the learning unit on sensors, and instrumentation and measurement systems, applications in various engineering fields are presented. This topic also covers operational amplifiers, and some basic types of instrumentation systems which are extensively used in all fields of engineering. The students are first provided an overview of the application of these systems in various engineering applications, and are then given concrete examples of how the sensors and instrumentation systems work in these applications. By using such real-world examples, and illustrating the fundamental concepts via simple building blocks, the lecturer is able to simplify the concepts and present them in a short period of time. Use of animations further allows explaining the concepts in a very efficient manner.

An example of how e-learning portal can effectively be used to present this large number of topics is presented below. To illustrate the workings of a differential amplifier, commonly applications in the medical field are used. An example is electrocardiographic (ECG) recording system, where the differential signal generated by the patient's heart appears between the electrodes. The student is shown how this tiny signal is amplified, even though a large 60-Hz common-mode signal is presented between the electrodes and the ground point of power supply, which needs to be suppressed (Fig. 5).

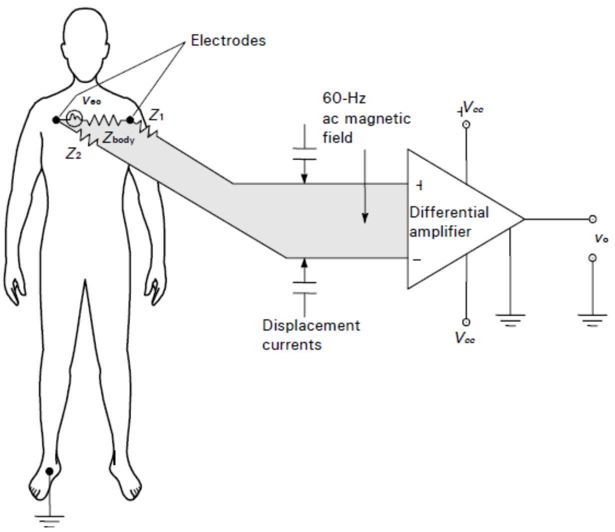

FIG. 5 APPLICATION OF DIFFERENTIAL AMPLIFIER IN INSTRUMENTATION SYSTEMS

After understating the workings of the amplifier, the student can try numerical problems through self-learning tutorials available for this e-learning unit. For example, the student can calculate the minimum CMRR for an electrocardiograph amplifier for various values of differential gains and the desired differential input signal amplitudes.

The example of a strain gauge is used to introduce sensors in the context of real world applications. A strain gauge is a type of sensor that measures deformation due to pressure (Fig 6). When the strain gauge is stretched, the conductor reduces its cross-sectional area and thus will carry less current. The strain gauge is fixed to the part on which the applied force is to be measured.

The students are shown the example of a strain gauge attached to a bridge, for measuring the strain on the bridge. The weight of the vehicles may cause the bridge to be strained, causing the strain gauge to elongate, resulting in change in its resistance. This change in resistance can be utilized to generate an output voltage signal using a Wheatstone bridge arrangement. The students can then click on the Wheatstone bridge electrical circuit and solve for the value of the resistance.

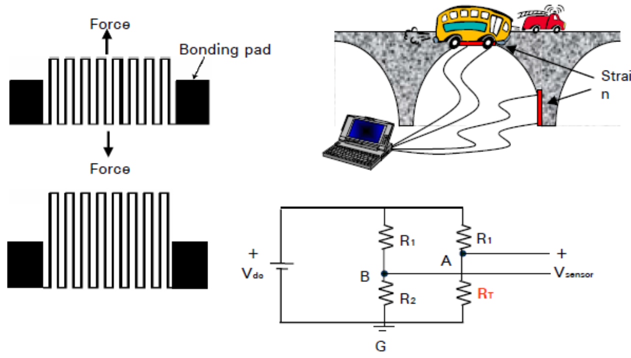

FIG. 6 STRAIN GUAGE AND WHEATSTONE BRIDGE CIRCUIT

Example 4: DC Motors

The e-learning portal has been designed to cover all the topics taught in this course. Use of flash animations and other multi-media techniques allows understanding on concepts in an efficient manner, for example where concepts from other courses form the foundation for more advanced topics covered in this course. For example, the students can use animations to understand the concepts from physics to understand the basic operation of a DC motor. In this topic, several animations have been developed to illustrate the concepts such as efficiency and power low in a motor, torque-speed relationships for various types of motors, and speed control of motors. Users are able to change the values of resistances to observe their effect on the speed of the motor (Fig. 7).

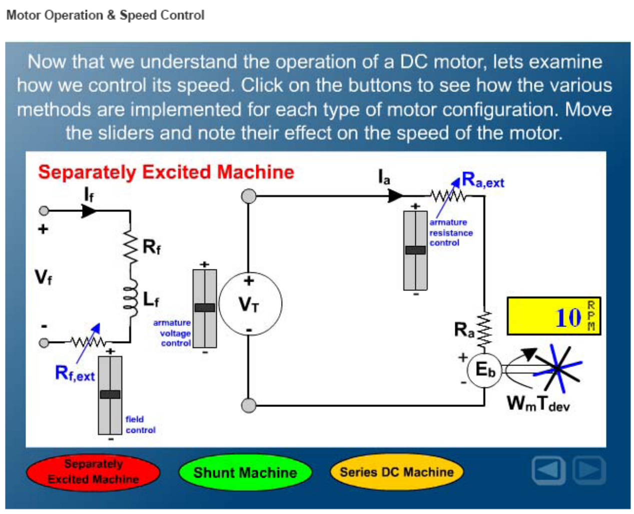

FIG. 7 SPEED CONTROL OF DC MOTORS

It is found that the extensive use of information technology, web-based e-learning tools and animations for further understanding of concepts is a major step towards the university's initiative towards the implementation of instruction tools that facilitate student-driven inquiry via network tools and databases at the undergraduate level. In turn, the educational process becomes a collaborative effort.

Fulfillment Of Intended Learning Outcomes

In this blended learning approach, great emphasis is placed on showing students how engineering fundamentals are critical to various broader issues, using a variety of teaching strategies, as circumstances seem to warrant. The e-learning components enable the students to develop a conceptual intuition. Mathematical equations are presented as a formal way of quantifying the relationships between physical properties, which helps the students internalize the information. Similarly, the application-oriented presentation of course content encourages an intuitive understanding where each topic is first presented with the final application of the concept, and then guides the students to learn how to achieve that. By going through a conceptual reasoning first, the concept already seems familiar when it is finally presented. A third way of achieving this conceptual intuition is to start with a simple system and work to the more complex one. Thus, by starting with a concept that is already intuitive, more complex pieces are incrementally introduced, while staying focused on the fundamental premise.

The extensive use of real-world applications allows students to actively engage in the learning process, and to learn-to-learn more effectively and with purpose. An increasing number of students have commented that they have found the use of real-life examples very useful in understanding concepts. In the student feedback comments on this course, a large number of them attributed their learning to the way they could relate the theoretical concepts to the real world.

This course has been offered to engineering students every semester for 8 consecutive semesters, with an average class size of 450. It was noted that the student performance consistently improved over the semesters as more and more e-learning features were incorporated into the teaching. It should be noted that the level of difficulty of test papers was about the same every semester, and the course was taught by the same lecturer.

Analysis of the data obtained from online student feedback forms obtained at the end of each semester showed that the students' perceived level of difficulty of the course reduced over the semester. In the first semester before e-learning features were implemented, 55.2% of the students found this course to be either too difficult or difficult, however as e-learning features were incrementally included and refined, this figure dropped to 33.1%.

The e-learning features have been extremely useful in teaching this large number of topics in a few hours, employing innovative ways to present the material in the limited time, and making it interesting and meaningful for the students. To this end, an effort has been made to balance theory and practice and use real-world examples that students can relate to. This is done by connecting the classroom to students' real-life experiences, by creating a context of engagement and participation.

Qualitative student feedback for the course has also showed that students developed better understanding of concepts and felt more empowered when these innovative teaching methods and strategies were used, and found the overall learning process to be more effective and enjoyable. Improvement in student learning is also demonstrated in the changes in the assessment outcomes for the course, where an increasing number of students have commented that they have found the use of real-life examples very useful in understanding concepts.

Conclusions

This paper presents a case study where a blended learning approach was employed in teaching a first year engineering course with extensive use of e-learning components, self-learning tutorials, videos and animations that allow the students to learn the concepts at their own pace. The e-learning portal provides a fully integrated overview of various electrical engineering application areas. Several web-based animations were developed to illustrate difficult concepts in electrical engineering in a simple manner, while relating the ideas in a practical context.Despite having very large number of students in each class, it was found that this blended approach helped the students study a diverse range of topics in face-to-face settings, such as lectures and tutorials, and allowed them to understand the concepts in a very flexible yet interactive manner through the e-learning components. The student feedback has been very positive, and the overall experience has been very rewarding. Student feedback data showed that students found the overall learning process to be more effective and enjoyable, and displayed better understanding of course content as demonstrated through various assessment tasks.

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Dipti Srinivasan received the M.Eng. and Ph.D. degrees in electrical engineering from the National University of Singapore (NUS), Singapore, in 1991 and 1994, respectively. In June 1995, she joined the faculty of the Electrical & Computer Engineering department at NUS, where she is an Associate Professor. Dr. Srinivasan is currently serving as an Associate Editor of the IEEE Transactions On Neural Networks and the IEEE Transactions On Intelligent Transportation Systems. She was awarded the IEEE PES Outstanding Engineer award in 2010.

She was the winner of NUS Annual Teaching Excellence Award in years 2007, 2008 and 2009, and was placed on the Honours list in 2010. She was the recipient of Engineering Educator Award from the Faculty of Engineering, NUS in 2011 and 2012.