Evolution of first year teaching of electrical engineering

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ABSTRACT: Highlighted in this paper are the developments of first-year teaching of electrical engineering at the University of South Australia (UniSA). The first motivation for change was a diminished enrolment of engineering students, which impacted the budget. The second motivation was to modernise the courses by aligning them with current industry practices. Increasing a programme or course attractiveness and industry relevance were seen as a means to address the budgetary position. This results in offering more variety and flexibility to students that lead to an inevitable fragmentation of the student population. An insight is presented in this paper into the evolution of the first year electrical engineering course at UniSA over two decades, from 1994 to 2013, which reflects the past, current and future developments. Changes to engineering curricula have occurred worldwide as a result of the modernisation of the engineering and science disciplines, technological developments and, also, due to economic factors. The UniSA case illustrates these overall trends.

INTRODUCTION

The first electrical engineering course/subject called Electric Engineering was offered in the third term of 1889 in the South Australian School of Mines and Industries founded in that year [1]. This was the predecessor of the South Australian Institute of Technology (SAIT) established in 1960. The SAIT was the predecessor of the University of South Australia (UniSA) that came into existence in 1991.

Electric Engineering covered the electric dynamo machine; the electric light and arc lamps; the incandescent or glow lamp; induction and intensity coils and miscellaneous electrical apparatus and appliances. Topic areas somewhat have changed but some are still in the curriculum in updated form. The note for candidates for Electric Engineering in 1889 stated: *It is useless for students who have no theoretical knowledge of electricity and magnetism to attend this class. Students are advised to attend Physics Class previously* [1]. The authors cannot restrain themselves from quoting some of the rules from Regulations for Students from the same document.

1. *Order and quiet must be observed in the School and Museum at all times*.
2. *Breach of discipline may be met with immediate suspension or dismissal*.
3. *No student will be allowed to enter an examination unless he shall obtain satisfactory report of conduct and attendance (at least 80 per cent) from his instructor, teacher, or lecturer* [1].

Tempora Mutantur…

The current paper illustrates that changes to the content and delivery of fundamental electrical engineering courses occurred every three to four years over the past two decades. There is no reason to believe that a different frequency was applicable in the past 124 years since the first Electric Engineering course was offered in South Australia. Change has been constant and persistent.

The evolution of electrical engineering courses for all engineering students between 1994 and 2013 is discussed in this paper. In this period at least three major restructuring exercises took place, affecting all engineering staff and students. In the following text, details of delivery and assessment of all the discussed courses/subjects are summarised in Table 1 and Table 2.

CIRCUITS AND DEVICES 1

The authors were involved in teaching the course since 1994. It covered basic electrical circuit theory, with the aim of providing students with a firm foundation in the study of electrical circuits and some elementary devices [2]. The course

was followed by Network Theory, and Circuit and Devices 2 and 3 - the latter ones covered in-depth analogue electronics.

ELECTRICITY AND ELECTRONICS

In 1997 the course, Electricity and Electronics, was introduced after a major review of all the engineering degree programmes in late 1995 and in 1996 [3]. It was offered by the School of Physics and Electronic Systems Engineering and was compulsory for all engineering students. The reciprocal course from the School of Engineering, encompassing the remaining engineering disciplines at UniSA, for all engineering students, was Mechanics and Materials offered by the School of Engineering.

The engineering degrees were split between an Information Technology option (Computer Systems Engineering, Electronic and Micro Engineering, Telecommunications) and a Resources and Infrastructure option (Civil and Water Engineering, Electrical and Mechatronic Engineering, Mechanical and Manufacturing Engineering, Mineral Resources). The two options were offered by the two Schools listed above.

The multidisciplinary first year was virtually common for both options and included foundation subjects from each option and science and mathematics fundamentals.

Interestingly, the Electrical Engineering discipline was seen as better fitting into the *hard engineering* disciplines, and the Electrical and Mechatronic Engineering degree together with a number of academics were transferred to the School of Engineering. It lasted only until 2000, when the philosophical differences of mechanical/civil and electrical engineering in both teaching and research became obvious. The academics and the course were transferred to the School of Electrical and Information Engineering renamed from the School of Physics and Electronic Systems Engineering.

The details of Electricity and Electronics offered in 2007 are as follows [4].

Course Aim

To provide an introduction to fundamentals of electrotechnology and its applications suitable for all engineering students.

Course Content

Overview, electrical engineering disciplines, components and circuits. Voltage, current, power, energy. Basic circuit laws, Ohm's law, KVL, KCL, basic electrical measurement instruments and procedures. AC fundamentals, complex numbers, phasors. AC power, AC circuit analysis. Capacitors, inductors, 3-phase circuits, power systems, transmission, distribution, protection, electrical safety. Energy conversion principle, transformer construction and characteristics. Electrical machines. Transients, diodes, rectifiers, voltage regulators, inverters, transistors as switches, logic circuits. Analog signals, transducers, amplifiers, noise, signal transmission, spectrum of signals, filters. Control system principles, feedback control, system stability, compensation. Communications, signal modulation, information transmission. OP-Amps, transistors as amplifiers. Digital signals, digital logic, sequential logic. Digital integrated circuits, microcomputers.

For the first time, up to 5% bonus points were introduced for the student course development attempt, e.g. solutions to the past examinations; PowerPoint presentations on current developments in electrical engineering; complex number calculator; conducting non-compulsory laboratory exercises, etc. These bonus points have been continued in the follow-up courses.

It is fair to state that those discipline-specific courses, such as Electricity and Electronics and Mechanics and Materials were not much liked by students outside the disciplines, despite concentrated efforts to make the courses as attractive as possible.

INTRODUCTION TO ELECTRICAL ENGINEERING

The course, Electricity and Electronics, was replaced in 2001 by Introduction to Electrical Engineering, with a more realistic, less crowded syllabus. The details of the course are listed below [5].

Course Aim

To provide an introduction to fundamentals of electrotechnology and its applications and an overview of electrical engineering. The subject aims to be suitable for all engineering students and for students from the School of Computer and Information Science taking a minor/major in Computer Systems Engineering.

Course Content

Overview of the disciplines of electrical engineering. Basic DC and AC circuit concepts and analysis. Concepts of power systems. Power plants, generation, transmission, distribution, protection, losses, efficiency. Transformers. Environmental issues. Principles of electrical machines. Special purpose motors. Motor selection and applications. Speed and torque control. Basic drives. Electrical safety. Introduction to electronic instrumentation and measurements. Fundamentals of measurement systems. Transducers. Signal conditioning. Data acquisition. Interfacing with General Purpose Interface Bus (GPIB). Electrical transients. Frequency response, resonance.

In this course students were prepared for the first time for computerised measurements.

ELECTRICAL AND ENERGY SYSTEMS

The course was defined and introduced in 2006 as part of the fully common first year engineering degree that sparked a major revolt by the School's academics. A delegation of five professors/associate professors of the School of Electrical and Information Engineering appeared at the Academic Board of the UniSA, in protest. The protesters claimed the course was demolishing a successful structure of the electrical engineering degree, eliminating some important electrical engineering content and exposing students to electrical engineering only in later years. It was also claimed that it reduced the School's income. The protest was ignored by the Vice-Chancellor and Pro Vice-Chancellors of the UniSA. The Academic Board voted for the changes.

The course was offered until 2012 as a common course to electrical, mechanical and civil engineering students. The latter students were the most vocal opponents despite the efforts of lecturers to present the relevance of electrical engineering to the students' prospective profession. From 2013 civil engineering students will not have any exposure to electrical engineering.

In any version of the first year of an electrical engineering course, about half of the course needs to be devoted to electrical circuit fundamentals. This is required as a prerequisite for electrical engineering students in Electrical Circuit Theory offered not in their second year of the degree.

The details of the Electricity and Energy Systems course are listed below with a screen shot of the Learnonline Web site of the course (Figure 1). As can be seen, the course content is much more open-ended than other siblings from the same family [6].

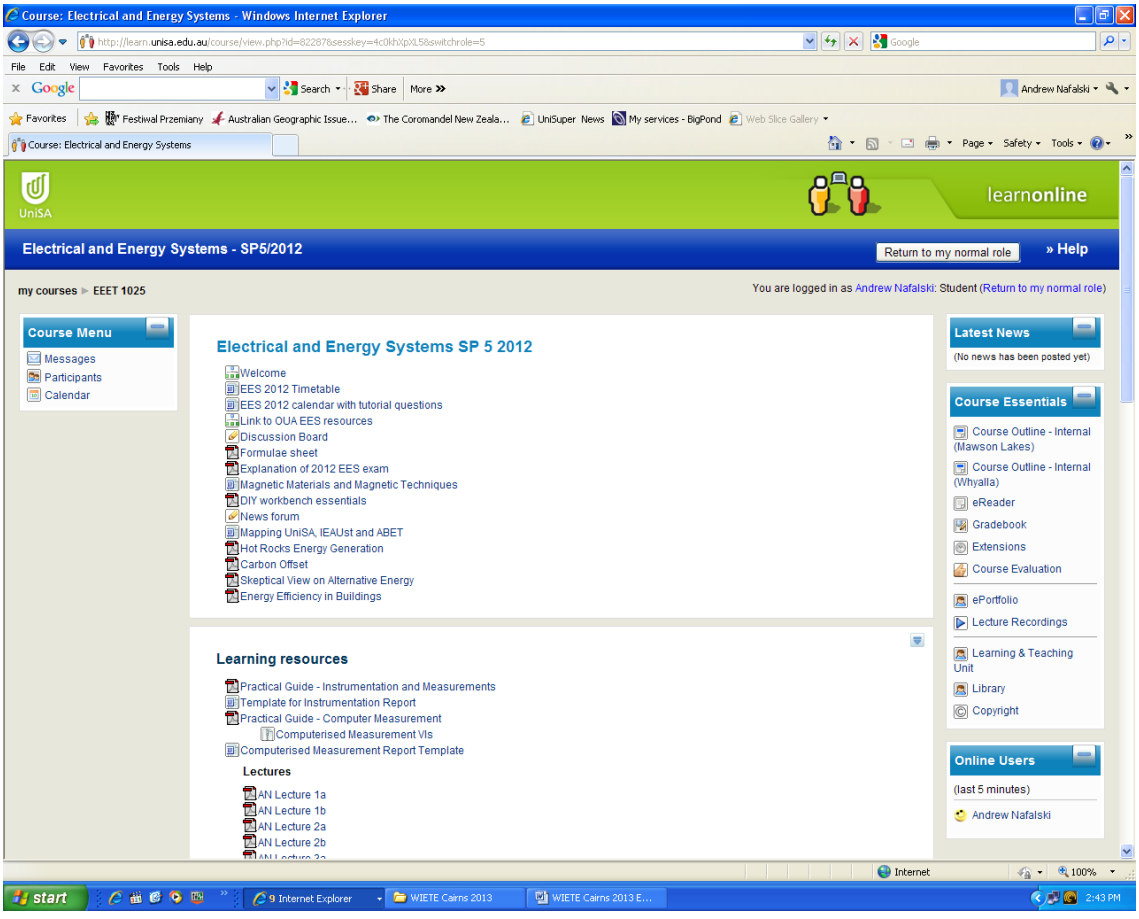

Figure 1. Learnonline resource of Electrical and Energy Systems course.

Course Aim

To introduce students to concepts, applications, basic analysis and measurements in electrical and electronic systems.

Course Content

Overview of electrical systems and applications. Basic DC and AC circuit concepts, laws and analysis. Power systems. Generation. Transmission. Distribution, Utilisation. Losses. Efficiency. Environmental issues. Sustainability. Electronic components and systems. Fundamentals of measurement systems. Analysis, presentation and interpretation of measurement results. Electronic instrumentation and measurements. Sensors. Transducers. Signal conditioning. Amplifiers. Computer-based measurements.

ELECTRICITY AND ELECTRONICS AGAIN

During 2011 and early 2012 a massive restructuring and redesign of engineering programmes in the School of Electrical and Information Engineering took place, driven top down to address reduction of enrolments in Electrical Engineering disciplines and to make them more attractive and relevant to potential candidates. The process started with the defining by *brainstorming* of the essence of electrical engineering, in terms of required knowledge and skills and, then, how these can be attained during the duration of the degrees. It was followed by more detailed discussions regarding content and the naming of individual courses. The end result was a suite of eight electrical streams to be offered in 2013 viz. Bachelors of Engineering in Computer Systems, Electrical and Electronic, Electrical and Renewable Energy Systems, Electrical and Mechatronic, Electrical and Systems Engineering, Electronics and Communications, Networking and Communications, and Optical and Electronic.

Complicating factors in the structural design were the common engineering first year, prerequisite requirements, sequencing semester offerings and partial or full commonality with programmes from mechanical engineering, such as the Bachelor of Engineering in Mechanical and Mechatronic Engineering and a new Bachelor of Mechatronic Engineering, the latter being fully shared between electrical and mechanical disciplines.

The details of Electricity and Electronics to be offered in 2013 follow [7].

Course Aim

To introduce students to concepts, applications, basic analysis and measurements in electrical and electronic systems.

Course Content

Overview, electrical engineering disciplines, electrical safety, components and circuits. Voltage, current, power, energy. Basic circuit laws, Ohm's law, KVL, KCL, basic electrical measurement instruments and procedures. AC fundamentals, rehearsal of complex numbers, phasors. AC power, AC circuit analysis. Capacitors, inductors, DC first order transients. Diodes, transistors, operational amplifiers - characteristics and applications. Computer-based instrumentation systems. Measurands and sensors, signal conditioning, data acquisition board, multiplexer. Noise, shielding, grounding. Analog-to-Digital conversion, sampling rate, sampling rules, sample and hold circuit, aliasing, quantisation, errors in measuring system. Introduction to Multisim, LabVIEW, MATLAB. Simulation of electrical/electronic circuits and processing of measurement results. Three phase systems, electrical power systems, environmental and economical aspects of electricity generation, transmission, distribution and use. Generator and motor action principles of electromechanical energy conversion. Modern magnetic materials and techniques. Transformers and electrical machines.

The most heated discussions about the new curriculum were on the first- and second-year course design, with inevitable clashes between colleagues who know more and those who know much less about early electrical engineering degree teaching. Also as expected, interests were expressed in preserving/extending course ownership by academics. By a popular vote, the Electrical and Energy Systems course was renamed *Electricity and Electronics*, the name perceived to properly represent the balance between the two areas. The first observation on the proposed course content is that it is dominated by electronic and computerised measurements that feature in all engineering practice nowadays. This means that the power engineering and electrical machine components in the course need to be greatly reduced. An additional justification for increasing the electronic part of the course was that it provided the only opportunity for mechanical engineering students to expand their skill base in this area before taking Electromechanics in second year.

Restructuring of Engineering

As a result of financial pressures a number of staff in Electrical and Information Engineering were separated out and the remaining staff of the School will be merged into the new School of Engineering from 1 January 2013. The cycle of repetitive occurrence is now visible: School of Engineering – School of Engineering, Electricity and Electronics and again the same later.

The Laboratory

The laboratory component of the course developed and implemented in 2011 and 2012 in Electrical and Energy Systems amounted to 40% of the assessment. It also will be implemented in 2013 in Electricity and Electronics, after some modification resulting from student feedback and supervisors' observations. The practical component of the course consists of two parts.

First part: In the Instrumentation and Measurement practical, students familiarise themselves with the use of modern digital instruments: a digital storage oscilloscope (Goodwill GW GAG-809), digital multimeters (two types: a DIGITECH auto-ranging and True RMS Uni-Trend UT803 multimeters) and a Goodwill GAG-809 signal generator, and learn how to acquire and transfer the collected data to USB, visualise it, and write reports with result analysis and discussion of errors.

Second part: The Computer Measurement practical is project-based and is a continuation of the successful project laboratory implementation of the first year curriculum [8] and, intentionally, is very much hands-on. Students solder a data acquisition/signal conditioning board PCB preceded by a soldering practice and, then, use the board to acquire, process and visualise signals, in six different exercises. Students usually work in teams of two.

The first sensor is a temperature sensor with which students learn data acquisition, conversion and logging with NI USB-6009 Data Acquisition Board. Heart pulse rate monitoring with piezo film vibration sensor is conducted in the second experiment. Four dimensional tilt sensor explaining position detection of smart phones, tablets and games is the next. It is followed by Charge, Transfer, Infrared (QTI) reflective sensor for reflectivity of surface measurements. Light measurement with a phototransistor follows, leading to a sampling rate and aliasing exercise. Seemingly, the sensor applications are relevant to all engineering disciplines as are the data acquisition and result processing using LabVIEW and MATLAB, and circuit simulation using NI Multisim. As the laboratory programme is relatively demanding, 30% of it is non-compulsory and it is for ambitious students only, to obtain the bonus marks.

The Electrical and Energy Systems and Electricity and Electronics courses were also developed for Open Universities Australia (OUA) delivery countrywide and for delivery to the UniSA regional campus in Whyalla (some 382 km NW from Adelaide). The use of the UniSA remote laboratory NetLab for the Instrumentation and Measurement practical was an easy and efficient choice for delivery for OUA and Whyalla students [9].

SUMMARY

The summary of the delivery and assessment of electrical engineering courses in the first year of engineering degrees at UniSA is presented in Tables 1 and 2.

Table 1: Delivery of the first year electrical engineering courses at UniSA.

Date introduced	Name	Lectures	Tutorials	Practicals
1993	Circuits and Devices 1	2 hrs x 13	2 hrs x 12	2 hrs x 5
1997	Electricity and Electronics	2 hrs x 13	2 hrs x 12	2 hrs x 5
2001	Introduction to Electrical Engineering	2 hrs x 12	2 hrs x 5	2 hrs x 5
2006	Electrical and Energy Systems	3 hrs x 13	1 hr x 10	2 hrs x 8
2013	Electricity and Electronics	3 hrs x 13	1 hr x 10	2 hrs x 8

Table 2: Assessment of the first year electrical engineering courses at UniSA.

Date introduced	Name	Exam	Mid-semester test	Quizzes	Practicals
1993	Circuits and Devices 1	45%	15%	20%	20%
1997	Electricity and Electronics	40%	10%	25%	25%
2001	Introduction to Electrical Engineering	40%	15%	20%	25%
2006	Electrical and Energy Systems	40%	formative	20%	40%
2013	Electricity and Electronics	40%	formative	20%	40%

Two important points to note are first the increase of the practical component of the assessment from 20% to 40% and the increase of its contact hours. These were introduced intentionally to give students a hands-on exposure to the electrical engineering discipline, in the attempt to motivate them.

The other important point is the removal of the mid-semester test from the formal assessment. It has been replaced by a formative test, which will give the same feedback on learning progresses without affecting their marks.

Forty per cent of the examination in the total assessment is about right, confirmed over the years; it allows for the evaluation of the individual knowledge and skills acquired during the semester, without the danger of plagiarism or *easy ride* report writing.

CONCLUSIONS

The evolution of first year electrical engineering at UniSA and most likely across the university sector worldwide indicates a very clear shift of emphasis, from traditional electrical engineering power topics in the first year electrical engineering courses, to electronics, electronic measurements and instrumentation, and computerised measurements, together with all related topics.

It remains to be seen whether this is going to disadvantage or benefit future generations of engineers.

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