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First-year teaching developments in fundamentals of electrical engineering

Andrew Nafalski & Hugh Considine

University of South Australia
Adelaide, Australia

ABSTRACT: Modernisation of engineering education including courses in fundamentals of electrical engineering has been happening continuously in response to the advancement of knowledge. Other factors for change include a need of aligning the courses with industry practices, and not least - the economic factors due to funding restrictions and diminishing enrolment demand. Once more esoteric, but now existing factors are also the perceived attractiveness of engineering degrees and how demanding they are for the students during their studies. In this article, is presented a review of the developments in fundamentals of electrical engineering at the University of South Australia (UniSA), Adelaide, Australia, during the three decades between 1993 and 2022. The illustrated evolution of content, delivery, assessment and organisational circumstances although limited to one institution in this review, is likely to be visible and applicable to other areas of university engineering education elsewhere now and in the future.

Keywords: Fundamentals of electrical engineering, evolution of content, teaching developments, student outcomes

INTRODUCTION

Teaching of the early-year electrical engineering courses at the University of South Australia (UniSA) - established in 1991 and its predecessors, the South Australian School of Mines and Industry (SASMI) (established in 1889 [1]) and the South Australian Institute of Technology (established in 1970) - went through continuous dynamic changes until current times. It reflected the changing landscape of knowledge content, teaching and learning developments, industry relevance and economic pressures. The first offering of electrical engineering fundaments named Electric Engineering happened 133 years ago at SASMI.

In the discussed period (1993-2022), at least five major restructures took place in the UniSA Engineering, followed by changes in structural allocation, content and prerequisites of electrical engineering fundamentals. At first, there was a structure of schools with reporting through a dean to the university level senior management team. Then, the faculties were replaced by divisions, with new school arrangements, which changed at least two times. Pro vice-chancellors were leading the divisions. The Division of IT Engineering and the Environment was then hosting engineering disciplines.

In 2013, the School of Electrical and Information Engineering (EIE) offering fundamentals of electrical engineering was absorbed by the School of Engineering; five full professors and many other staff in the EIE were made redundant. In 2020, the university structure was replaced by UniSA academic units - in the engineering case - UniSA STEM, with executive deans heading them.

There have been many remarkable changes in *modus operandi* of electrical engineering courses. A major one was the on-line delivery of fundamentals of electrical engineering components. The Open Universities Australia (OUA) programme was made available nationwide and internationally in 2012 with most of the components available in on-line mode, partially including laboratory components [2].

In 2017, the UniSA Online was created offering currently twenty-eight 100% on-line, career focussed degrees [3], and taking responsibility for the OUA Associate Degree in Engineering from 2021. The UniSA Online hosts the course called Electrical and Electronic Systems.

In this article, the authors review the last three decades of changes of content, delivery, assessment and organisational circumstances resulting from economic and other pressures, in which first-year electrical engineering courses at UniSA were delivered to the students.

CIRCUITS AND DEVICES 1

The authors were involved in teaching of the course between 1994 and 1996. It then covered basic electrical circuit theory principles and was offered to first-year electrical engineering students only. It was followed by Network Theory, and Circuit and Devices 2 and 3 - the latter ones covered in-depth analogue electronics.

ELECTRICITY AND ELECTRONICS

After a major review of all engineering programmes in 1997, the course Electricity and Electronics was offered by the School of Physics and Electronic Systems Engineering, later renamed to the School of Electrical and Information Engineering (EIE), the name better reflecting the majority of disciplines in the School. The course was compulsory for engineering students and aimed to provide introduction to electrotechnology and its applications suitable for all engineering students.

Another course compulsory to all engineering students was Mechanics and Materials delivered by the School of Engineering. The purpose was to create a virtually common first year of all engineering studies to benefit from the economy of scale and to expose the students to all engineering disciplines.

It did not work all perfectly as students from *opposite* sides of engineering (mechanical *versus* electrical) did not see the relevance of the other courses to their future careers, which affected their motivation. It was despite of the commitment, dedication and efforts of involved academics. The commonality also created problems with prerequisites and the necessity of shifting some courses into later parts of the curriculum.

Nota bene, one of the authors of this article studied his BEng degree in electrical engineering in the 1960s with totally common first year called General Technology, with exposure to very *mechanical* theoretical and practical aspects, such as moulding and casting, wastewater monitoring and management, and structural analysis leading to design of a lifting jack. For six months, the first-year students had also two days per week, practical experience in industry, working on a lathe and a production line of motorcycles, among other exposures to the industrial environment. From the perspective, it widened their understanding of life.

INTRODUCTION TO ELECTRICAL ENGINEERING

In 2001, the course Electricity and Electronics was replaced by Introduction to Electrical Engineering, with a more realistic, less crowded syllabus, with a sizeable amount of electronic instrumentation and measurements, including computerised measurements. It was mandatory to all engineering students and also to students in computer science taking major/minor in Computer Systems Engineering.

ELECTRICAL AND ENERGY SYSTEMS

The course introduced in 2006 as part of the fully common first-year engineering degree raised major opposition of the EIE School’s academics. The delegation of senior academics lobbied the Academic Board, VC and PVC against it for pedagogical and economic reasons. All of these appeals were ignored.

The course introduced students to concepts, applications, basic analysis and measurements in electrical and electronic systems. Student assessment included project-based laboratory work [4]. The course was offered until 2012 [5].

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 the reduction of enrolments in electrical engineering disciplines, to make them more attractive and relevant to potential candidates.

By a popular vote the Electrical and Energy Systems course was renamed in 2013 to Electricity and Electronics, the name perceived to properly representing the balance between the two areas. The course content included basic analysis of electrical and electronic systems, and was meant to increasingly expose students to electronic and computerised measurements that are core components of all engineering practices nowadays.

The course was offered for eight electrical streams/degrees of BEng in electrical engineering and two degrees in mechanical engineering.

ELECTRICAL AND ELECTRONIC SYSTEMS

This course started in 2019 introducing students to the basic principles of electrical systems and electronic circuits. Electronic circuits were described in terms of basic electrical quantities, components and circuit analysis methods. Electrical systems, such as power supply were introduced in the context of renewable and non-renewable supply,

transmission and storage [6][7]. The course was common in the first year for all nine current engineering degrees - BEng (Hon), albeit it was shifted to the second year in the two-year Associate Degree in Engineering. It is also present in double degrees of BEng (Hon) and BBus.

THE LABORATORY

Practicals have generally aimed to introduce the basic components and measurement tools that students must use, and have changed as technology has changed.

An increased project-based component was included in the laboratories of courses prior to 2010 [4]. The laboratory component of the course developed and implemented in 2011 and 2012 in Electrical and Energy Systems was increased to 40% of the assessment. It was later implemented in 2013 in Electricity and Electronics and following incarnations, after modifications as a result of the student feedback and supervisors' observations. Electronic instrumentation [8] and computerised measurements components were gradually increased in the laboratory programmes.

In 2012, practical work consisted of instrumentation and computerised measurement practicals. In these practicals were used a variety of laboratory instruments in conjunction with LabVIEW. As the mechatronics programme moved away from LabVIEW, the first-year course followed. From 2013 to 2018, several different projects were used for laboratory work.

In 2019, along with the conversion to Electrical and Electronics Systems, the Arduino microcontroller platform was introduced, based on the requirements of the higher-level courses. In all offered practicals, students were introduced to components including resistors, capacitors, diodes and inductors, tools including breadboards, and digital instruments including function generators, multimeters and oscilloscopes.

NetLab

The remote on-line open-access laboratory NetLab has been in operation at UniSA since 2002 [9] and was continually improved by generations of BEng, Master and PhD students, and involved staff. Over the years, the use of NetLab has become more prominent in laboratory offerings for both domestic and international students (studying on-campus, on-line or in a hybrid mode).

The development of an automated real-time student support system in NetLab based on learning analytics [10][11] has led to a visible improvement of student outcomes [12].

ON-LINE TEACHING AND ASSESSMENT

On-line Teaching

The introduction of the Lecture Recording System at UniSA in 2011 has automated the recording of all lectures. For the Open Universities Australia course from 2012 onwards, lecture summaries have been developed, allowing students to view at any time all lecture material broken into smaller portions. The on-line environment of the course Electrical and Electronic Systems is shown in Figure 1.

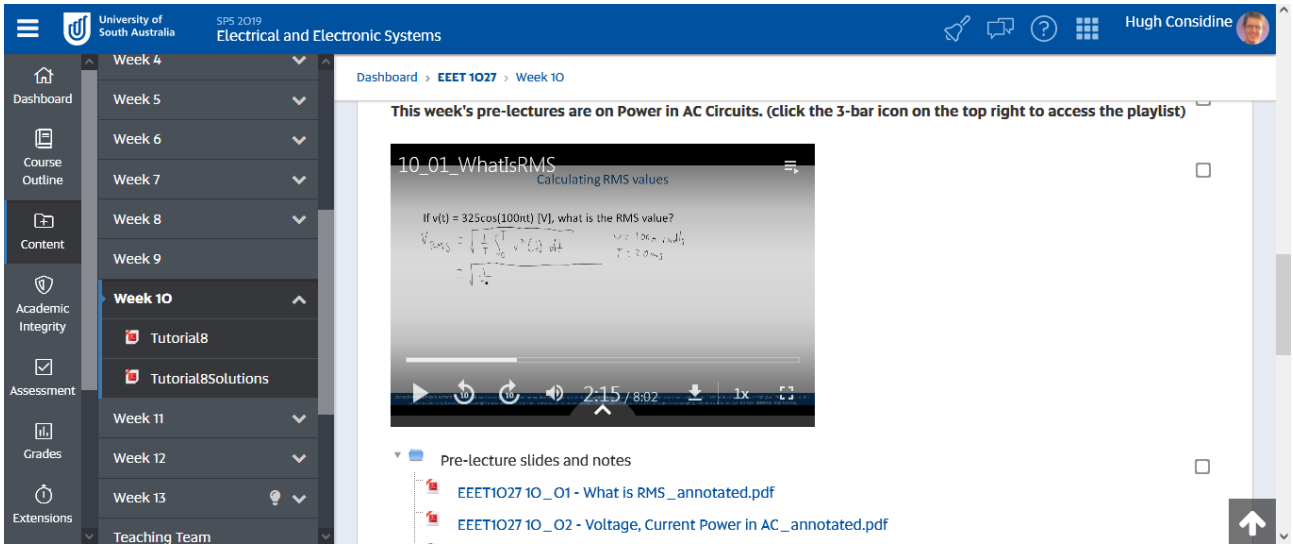

Figure 1: UniSA on-line learning system showing the 2019 Electrical and Electronic Systems course.

On-line offerings of the course have always covered the same topics as the on-campus versions of the course, but with suitable adaptations to the assessment as needed.

On-line Assessment

As Internet use has become more prevalent, an increasing amount of assessment has been moved on-line. A major change came with the introduction of the OUA offering of the first-year course in 2012. The first practical became an on-line practical using NetLab, and all students were required to submit work on-line.

In 2015, the Mastering Engineering system by Pearson [13] was introduced for weekly quizzes. Instead of quizzes being conducted in class, they were conducted on-line using the system which generated different questions for each student. The OUA course still required students to travel to the campus for most practical work, and to attend examinations in person at an examination centre, except when it was prohibited due to the pandemic.

In 2019, practical assessment was also moved on-line, with students conducting practical exercises in a laboratory, but then entering their results into an on-line quiz for each practical to be assessed. The development of a fully on-line version of the course for UniSA Online in 2020 meant moving all laboratory practicals to an on-line simulator. Social distancing requirements in 2020 then caused the adoption of some of the simulation practicals for students studying on-campus, with half of the students using a simulator each week, while the other half attended a laboratory practical.

International Teaching Using NetLab

NetLab was increasingly used in laboratory components of the first and second year of UniSA Bachelor degrees in electrical engineering in teaching outside Australia, in Singapore and Sri Lanka. It was also applied in other locations, such as degree studies in Sweden (Blekinge Institute of Technology) and Poland (Lublin University of Technology). In Poland, it has been used in Master and PhD degrees for over 10 years now, in disciplines of electrical engineering and information technology in a number of courses, leading to very positive student feedback and assessment outcomes [14][15].

SUMMARY

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

Table 1: Developments in the delivery of 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		2 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
2019	Electrical and Electronic Systems		2 hrs x 13	1 hr x 12	2 hrs x 10

Table 2: Assessment in first-year electrical engineering courses at UniSA.

Date introduced	Name	Examination	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%
2015	Electricity and Electronics	40%	Assignment 25%	10%	25%
2019	Electrical and Electronic Systems	40%	Assignment 20%	10%	30%
2020	Electrical and Electronic Systems	Take-home examination 40%	Assignment 20%	10%	30%

The two observations are important. One is the removal of the time-limited mid-semester test from the formal assessment. It was replaced by a formative test, which will give the same feedback on students' learning progress without affecting their marks. The formative test was later replaced with untimed assignment work, in which students had the opportunity to verify their answers using alternative methods.

The other observation is the changes to the examination over years. Forty percent of the examination in the total assessment is about right, confirmed over the years; it allows evaluating individual knowledge and skills of the students acquired during the semester, without a danger of plagiarism or *easy ride* in report writing. Due to restrictions caused by the Covid-19 pandemic, in 2020, the examination was changed to an uninvigilated *take-home examination*, in which students had a limited number of days to answer more open-ended questions than an examination would typically cover.

CONCLUSIONS

Changes to the names, content, delivery and assessment of courses in fundamentals of electrical engineering occurred at UniSA approximately every five years over the last three decades. These were in parallel with or dictated by organisational reconfigurations at the University. This is not unusual in the dynamically changing university sector in Australia and internationally.

The changes have been driven by many factors - requirements from accrediting bodies, changes to degrees structure (in particular the common first year for all engineering disciplines), and application of new teaching options, including on-line accessible lectures and tutorials, and advanced on-line quizzes with changeable parameters.

The evolution also includes remote laboratories, new digital measurement technologies and simulations, leading to the availability of fully on-line engineering degrees. There are examples that such on-line degrees have been accredited in Australia by Engineers Australia and/or the Tertiary Education Quality and Standards Agency. All the evolving incorporations of the fundamental electrical engineering courses were aimed at improving students' educational experience and outcomes. The student feedback seems to confirm the intentions.

In this article, the authors offer a rare insiders' view of academics teaching fundamentals of electrical engineering between 1993 and 2022 in one university and initiating, affecting and/or observing transformations of the very important initial courses providing foundation for further electrical engineering education. It is anticipated that the article will resonate in the circles of educators of fundamentals of electrical engineering outside UniSA.

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Professor Andrew Nafalski, BEng (Hon), GradDipEd, MEng, PhD, DSc, has over 50 years of academic experience in Poland, Austria, Germany, Wales, Japan, France, USA, Canada and Australia, including 32 years of employment at professorial and other senior leadership levels. Currently, he is an Adjunct Professor of Electrical and Information Engineering at the University of South Australia, Adelaide, Australia, and an Honorary and Visiting Professor at Lublin University of Technology, Lublin, Poland. His major research and teaching interests cover electromagnetism, learning technologies, including remote laboratories and on-line teaching, information technology applications in engineering and science. His publication record amounts to over 400 peer-reviewed items including 41 books and book chapters, 133 journal and 235 conference papers.

Dr Hugh Considine, BSoftEng (Hon), BEng (Comp Sys), PhD, is an on-line lecturer at the University of South Australia, Adelaide, Australia. He has been a tutor and practical supervisor for first-year electrical engineering courses at UniSA since 2011. In 2021, he completed a PhD with a focus on on-line engineering education, developing and evaluating a real-time student support system for a remote laboratory, using learning analytics. He published 16 peer-reviewed publications related to his PhD, including four book chapters and seven journal articles.