

DECENTRALISATION OF AN ELECTRICAL ENGINEERING COURSE FOR NON-ELECTRICAL ENGINEERING STUDENTS

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Abstract: In this paper we propose the concept of decentralisation of a course given as a service course by the School of Electrical and Information Engineering at The University of Sydney for non- electrical engineering students (ie, students who are not majoring in electrical engineering). This concept is supported by extended discussion of several conceptual fundamentals in university teaching and learning, that is: (1) student focused teaching, (2) coverage against understanding; and (3) assessment facilitating student learning. The course is compartmentalised into three relatively non-connected blocks. Taking into consideration students' interest, background and learning difficulties, teaching is focused on guiding students in building up the basic concepts of electrical engineering rather than detailed techniques such as in the professional electrical engineering units. The key to the change and improvement in student learning is assessment. The traditional single end-of-semester examination is decentralised by three tests, each one immediately after the relevant block of teaching. The discussion relates to one course but the principles may be applicable to other courses given as service-type units for students majoring in another discipline.

INTRODUCTION

There are four schools/departments in the Faculty of Engineering, The University of Sydney: the School of Aerospace, Mechanical and Mechatronic Engineering, the School of Electrical and Information Engineering, the Department of Civil Engineering and the Department of Chemical Engineering. To build up a broad knowledge of engineering many non-electrical engineering students are required to undertake some electrical engineering studies. In previous years, there were two 4 credit point courses for these students, in year 1 and year 2 respectively. From 2005, these became a single 6 credit point course: ELEC2004 Electrical Engineering Foundations. On the one hand, the non-electrical schools wish their students to have as much knowledge as possible of electrical engineering that may play an important part in their future careers. On the other hand, the schools do not have the luxury of courses to spare on material in other engineering disciplines. After careful consideration, and actually a reduction from the previous

Proceedings of the 2005 ASEE/AaeE 4th Global Colloquium on Engineering Education
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year's syllabus, the ELEC2004 Electrical Engineering Foundation course was designed as follows:

This course assumes a degree of basic research skill and ability to grasp engineering principles; information literacy; personal and intellectual autonomy; communication skills.

The following topics are covered. Introduction to circuits: current and voltage, power, Kirchhoff's Laws, sources and resistors, Ohm's Law, series and parallel connections, voltage divider, equivalent circuits. Inductors and capacitors: capacitance, inductance, inductors in series/parallel, RC circuits, RL circuits, transient and steady state, introduction to RLC circuits. Power transmission: sinusoidal signals, phasors, power in ac circuits, balanced 3-phase circuits. Transformers: characteristics of ideal transformers, introduction to magnetisation and non-ideal behaviour. Electromechanical energy conversion: machine types, DC machines, field connections, introduction to ac and induction machines. Operational amplifiers: ideal op amp, inverting amplifier, noninverting amplifier, design and gain-bandwidth product, simple filters. Logic circuits: basic concepts, number representations, combinatorial logic circuits, sequential logic circuits, introduction to CMOS digital circuits. Introduction to microprocessors: organization, memory, process control, instruction sets, addressing and interfacing.

There are 2 hours of lectures and an average of 1 hour of tutorial and 1 hour of lab per week. The assessment includes tutorials and quizzes of 10%, lab performance and notebook of 10%, assignment of 5% and a 2-hour closed book end-of-semester examination of 75%.

Unlike other professional courses that often deal with particular centred topics or subjects, this course tends to cover many key issues in electrical engineering, from basic circuit analysis to power engineering, from electromechanical energy conversion to analogue and digital electronics. These topics are normally learned by electrical engineering students in several separate courses, over several semesters. Now non-electrical students, in their second year, have to learn them all in one single course, and the lecturer has to present this vast amount of material in 24-26 lecture hours. In previous years the lecturer went through more than 20 slides an hour, with each of them containing a large amount of information. It is not difficult to imagine that students hardly understood anything and sometimes the attendance at lectures was under 20%. However, students had to pass this core (compulsory) course so they took every opportunity to gather information from previous exam papers, tutorial questions and hints given by the lecturer and hoped for good luck when they sat for the end-of-semester, 2-hour closed book examination. This gloomy picture was reported by students. Some students have attended the unit more than twice but have not yet passed. "Our students hate electrical courses", a liaison academic colleague from the non-electrical school commented more than once. No lecturer likes to teach a course students hate.

However, real life is not perfect. As mentioned before, the school wishes students to have a broad knowledge of electrical engineering but does not have the luxury of spare courses (or teaching and learning time) to spend on it. While it appears that the course design prohibits good teaching and student learning, the rest of the paper will discuss some pedagogic issues related to this

course and provide a proposal, actually a practice for improving the teaching and learning in this course.

STUDENT FOCUSED TEACHING

In recent years there has been increasing interest in research on learning and teaching in engineering education by teachers. In their book Prosser and Trigwell restated their studies on student learning perspective and experience as well as teachers' teaching perspective and experience. The teacher-focused teaching approach is based on the concept that teaching is transmitting knowledge from the teacher to students. Student-focused teaching is based, however, on the concept that teaching helps student to develop knowledge. "The relation between teachers' experiences and their students' experiences is such that university teachers who adopt a conceptual change/student-focused approach to teaching are more likely to teach students to adopt a deep approach to their learning, while teachers who adopt an information transmission/teacher-focused approach to teaching are more likely to teach students who adopt surface approaches to their study." (Prosser, M. and Trigwell, K., 1999, p162).

There are many issues in the development of student-focused teaching have been discussed in the above book. Our experience further shows that the teachers' understanding of the students and students' learning is extremely important. Every course is unique and the students are different. Even the same group of students may have different learning attitudes in different courses. A central point for student-focused teaching, therefore, is to know, to understand, the students. This concept may link to another sensitive topic in education research, that is, teachers' pedagogical content knowledge initially raised by Shulman (Shulman, 1986). Pedagogical content knowledge is developed on the basis of content knowledge and general pedagogical knowledge (van Driel et al, 2001). This development allows teachers to manage and present the technical knowledge of the course efficiently and comprehensibly to students. Surprisingly, Viiri has found, in his study, that the general pattern of student thinking was so far different from teachers' expectation that it astonished the teachers in the study, and should so the readers. "Teachers' knowledge - or perhaps, their non-knowledge - of their student's conception suggests that we shall need to emphasize this aspect in our teacher education courses." (Viiri, 2003). Clearly, student-focused teaching cannot be done without turning this non-knowledge to knowledge of students. Teachers must know their students, not only the strength; perhaps, more importantly, the weakness and learning difficulties of the students.

Returning to the course under discussion, aside from the vast amount of material listed in the syllabus, the learning attitude and approaches of students attending this course (and probably other courses for students not majoring in the discipline) are quite different from those in the major professional courses, even for the same group of students. Firstly the students have only limited interest in the "non-major" areas. Secondly, the background of the students in the "non-major" area may be quite weak. Some students attending this electrical engineering course only have some relevant knowledge from their high school physics studies, and others have none. For whatever reason we now put them into a single course covering many different topics and techniques, and the teacher must realise the students' learning situation and difficulties. Otherwise, if the teacher just focuses on the transmission of the content knowledge then he or she may teach the material no differently than if teaching students majoring in the discipline, except for making it more compact. In this situation it is particularly worthwhile to review the follows:

Good teaching involves finding out from students and other sources about the difficulties students experience in learning the subject matter, finding out about key outcomes that are not achieved or are only partially achieved, and considering the needs of particular group of students. High quality education cannot occur unless these activities take place. (Ramsden, 2004, p131).

What is required is an understanding of some general principles for good learning and teaching, careful monitoring of what students are experiencing in their learning situations and how they are doing so, and the awareness of a range of responses that can be made to emerging situations. (Prosser and Trigwell, 1999).

In the design and development of teaching strategy for this “non-major” course, we need to take all the facts into consideration: students’ interest, background knowledge, their learning ability, and especially learning difficulties. It is important to stimulate students’ interest in this different, “non-major” engineering discipline, connect it with their own engineering discipline major, guide students in understanding the basic concepts and very importantly, avoid falling into purely, unnecessary academic/technical details such as is required for students majoring in electrical engineering.

COVERAGE AGAINST UNDERSTANDING

There is a clear conflict between the coverage desired by the school and the ability of efficient students to learn the material in a limited time. In the past, the breadth of the course caused not only difficulties in student understanding, but also confusion among students about what they really needed to learn. There was little understanding.

The greatest enemy of understanding is coverage-I can’t repeat that often enough. Obviously, if people took this aphorism seriously, there would be a total revolution in education, and 95 per cent of what educators do every day would have to be changed (Gardner 1993, 24)

In this situation, students tend to gather pieces of information that they believe useful in the final examination and gamble on guessing the examination questions based on previous examination papers and hints given by the lecturer. This was mostly done immediately before the examination. Some students just tried to remember solutions for typical questions and hoped they could be modified to satisfy similar questions in the examination. Students could not even memorise the key concepts introduced. This fits perfectly the comments made by Ramsdan:

Anyone who has ever done any academic research will be aware of the devastating influence on the quality of output of an excessive number of small but different demands on one’s time. The inevitable result of too much busy work is that many students adopt minimising strategies and complete their courses with sketchy and confused knowledge of the topics they have ‘learned’. (Ramsden, 2004, p132).

This is the basis of the concept of compartmentalisation and further “decentralisation” in assessment for this “non-major” course. The material covered by this course, if we have no choice other than to collect it all into one single course, is spread over several topics/areas of electrical engineering. The topics are under a big umbrella but actually have limited connection from the point of view of teaching and student learning. For instance, knowledge of AC power

and three phase power systems has very little impact on studies of electronic circuits, nor does basic circuit analysis theory closely connect to digital logic. If we have good reason to put the topics into one single course, then we have even better reason to separate them clearly, or compartmentalise them to facilitate student learning and understanding, even if still in the same course.

It is then proposed that this course be compartmentalised into three parallel and discrete blocks:

1. **Introduction to Electric Circuits:** current and voltage, power, Kirchhoff's Laws, sources and resistors, Ohm's Law, series and parallel connections, voltage and current divider, equivalent circuits. Inductors and capacitors in RC, RL circuits, introduction to RLC circuits.
2. **Electric Power Systems:** sinusoidal signals, effective (rms) value of sinusoids, concept of impedance, power in ac circuits, transformer principles and ideal transformers, balanced 3-phase circuits. Electromechanical machine types, introduction to DC machines and AC machines.
3. **Basic Electronics:** Op amp, inverting amplifier, noninverting amplifier, other op-amp circuits. Digital signals and circuit, truth table and basic logic functions, Boolean function, digital circuit design and realisation. Introduction to microprocessors, example of instructions.

Each of the blocks deals with a central topic with a group of relatively closely connected concepts. The lecturer and the students need to establish a "concept centred" teaching and learning strategy. Students are required to understand the basic electrical engineering concepts and to demonstrate their understanding through basic problem solving. However, there is no focus on comprehensive electrical engineering techniques and complex problems, and students may take a deeper study of these topics for their own interest.

We enunciate two educational commandments, 'Do not teach too many subjects,' and again, 'What you do teach, teach thoroughly.' The result of teaching small parts of a large number of subjects is the passive reception of disconnected ideas, not illumined with any spark of vitality. Let the main ideas which are introduced into a child's education be few and important, and let them be thrown into every combination possible. The child should make them his own, and should understand their application here and now in the circumstances of his actual life. (Whitehead 1929: 2)

STUDENT CENTRED ASSESSMENT

The most crucial strategy in the "decentralisation" of this course is in assessment. "It is quite usual for lecturers to regard assessment as having a purely 'summative' function (serving to report students) and as having nothing to do with teaching them at all" (Ramsden, 2004, p179). The two-hour, closed-book end-of-semester examination served as only a grading mechanism with little positive impact on student learning in this course. At the later stage of the course, after many weakly-connected (if not isolated) aspects and disciplines, the concepts introduced at the beginning of the course appeared so remote that students hardly connected them with the materials currently being studied. The signal sent to students was that the reward was limited

even if they had a deep understanding of the topic at the beginning of the course because they would almost have forgotten it when it came to the examination. At the end, purely for the purpose of the examination, students just gathered some pieces of information and tried to memorise the steps for solving most possible examination questions.

This end-of-examination created a great deal of pressure for students. It was too much, students commented. It is like wandering among many isolated topics without an idea of what to do. The difficulties and pressures for students are inevitable and obvious. Quite frankly, I have asked my colleagues at an academic meeting: imagine that we are put into a one-semester course, as a fast-track training program, with all the key issues and techniques in Mechanical Engineering or Civil Engineering. At the end, our fate of pass or fail is determined by a two-hour closed-book examination. Could we handle it? My answer is: No, I cannot do it. If we would find it difficult then we should not require students to do it. This examination has little good effect on student learning.

In their editorial, Graaff and Rompelman wrote: "For a long time assessment of student learning results has been regarded by many as a minor issue to be taken care of after the important teaching tasks are over. However, awareness is growing that assessment methods are an integral aspect of the engineering curriculum, allowing both teachers and students to gain insight into the learning results of a course. Depending on the type of assessment method and the timing, assessment can fulfill different functions in an educational programme." (GRAAFF and ROMPELMAN, 2004).

Many researchers pointed out that assessment would hold the key to change student perception of learning and understanding (Dochy and Moerkerke, 1997). As Hargreaves (1997: 403) indicates:

Assessment is vitally important to students and exerts a major influence on their approach to learning. Assessment procedures should therefore promote and reward the achievement of desired learning outcomes. Teaching, learning and assessment are inextricably linked.

To make assessment a key role in facilitating student learning in this course, and in accordance with the three block structure of the proposal above, we "decentralise" the end-of-semester, 2-hour examination with three tests: one immediately after each block is concluded. The impact of this change to student learning is that they have a clear goal in each block of learning and significant reduction in the pressure of handling the massive amount of material at the end of the semester. Students build up confidence in learning this material and try to understand the electrical engineering concepts introduced. The results in early test(s) may also influence the learning behavior of students.

COURSE PLAN

Based on the above discussion, we have carefully designed the course to facilitate student learning. We have tried to organise as many tutorials as possible because they provide the best way for students to understand the concepts introduced in the lectures. In the selection of tutorial questions we again focussed on the understanding of basic concepts and avoided complex problems that require special electrical technical skills. The tutorials are marked with a total of 13 marks but the marking scheme is to check if the student has "genuinely attempted" the questions rather than if the solutions are correct. This encourages students' attempt at understanding and solving questions with their own effort. We also designed 4 laboratories in the course, basically

one for each block, but the AC transformers and motors is an additional one since it needs special care with high voltage appliances.

The total assessment scheme includes

Closed book Test 1,	25%
Closed book Test 2,	25%
Closed book Test 3,	25%
Laboratory	12% (3 marks per lab)
Tutorial	13% (1.3 marks per tut)

The course plan is listed here for reader's reference.

Lecture Sequence for 2005

Monday of the Week	Chaps	Lecture Topic	Tut/Lab
1 07/03	1.1-1.3 1.4-1.6	Introduction, units, quantities & measurements, Kirchhoff's Current Law, Kirchhoff's Voltage Law, energy flow, resistive circuits	No Tut/Lab
2 14/03	1.7	Series and parallel connections voltage divider, current divider	Tut 1: Resistive circuit, Kirchhoff's Laws
3 21/03	2.2: p64-67, 72-73	Thevenin's equivalent, Source transformation	Tut 2: Basic Circuit Analysis Friday a public holiday
28/03	MID SEMESTER BREAK		
4 04/04	3.1	Inductors and Capacitors	Lab 1: DC Circuits
5 11/04	3.2	First order circuit	Tut 3: Equivalent circuit First order circuit
	4.1 p148-151	Sinusoids Effective (rms) value of sinusoids	
6 18/04	5.1, p211-215	Power in AC circuits	Tut 4: AC circuit and AC Power
Test 1 on Friday 22/04			
7 25/04	5.3, p229-232 P 242-246 6.1, p260-262	Transformer Principles Ideal transformers Electrical Safety Introduction to 3-phase circuits	25/04 Monday a public holiday
8 02/05	P262-265 P267-271 P275-276	Source Delta connection and Y connection Load Delta connection and Y connection Per-phase circuit	Lab 2: AC Circuit and Power
9 09/05	17.1, 17.3 16.1, 16.3, 18.3	Solenoid and DC machines Induction machine	Tut 5: Transformers, 3-phase circuit, Motors

10 16/05	9.4, p489 P491-493 (Eq 9.105), p494-495 (Eq. 9.109)	Introduction to Op amps Basic Op-amps (inverting amps, noninverting opms)	Lab 3: Machines Lab
Test 2 on Friday 20/05			
11 23/05	P496-501	Linear Op-amp circuits (Buffer, Summing cct, Integrator)	Tut 6: Op-amps
12 30/05	8.1 p382 P384-385 p385-386 also p397 p393	Introduction to digital signals Truth tables Basic logic functions: NOT, OR, AND Boolean algebra	Lab 4: Op-amp Lab
13 06/06 10/06	P398-399 Hand out materials	Design and realisation of logic functions Introduction to microcontrollers	Tut 7: Digital circuits
Test 3 on the scheduled Examination day (one hour)			

CONCLUSIONS

In this paper we propose the concept of compartmentalisation/decentralisation of an electrical engineering course for non-electrical engineering students based on extended discussion about several conceptual fundamentals in university teaching and learning. That is, student-focused teaching, coverage against understanding and assessment facilitating student learning. The course is compartmentalised into three relatively non-connected blocks that can be learned separately. Taking into consideration students' interest, background and learning difficulties, teaching is focused on guiding students in building up the basic concepts of electrical engineering rather than detailed techniques such as in the professional electrical engineering courses. The key to the change and improvement in student learning is "decentralisation" of the assessment. Three tests, each one immediately after the relevant block of teaching, are designed to replace the single end-of-semester examination. The discussion relates to one course but the principles may be applicable to other courses for students majoring in another discipline.

When writing up this paper the proposed teaching strategy is in practice for the first time, in the School of Electrical and Information Engineering, The University of Sydney. We are quite sure that teaching and learning quality has improved although further study is needed. Some promising signs are that the drop-out rate is very low and attendance at lectures has been about 80%. Student reflection will be collected and analysed. We have no doubt that this will further improve the proposed teaching strategy.

ACKNOWLEDGEMENT

This innovation in teaching and student learning has been strongly supported by the School of Electrical and Information Engineering and the Engineering Faculty, the University of Sydney. Productive discussions have been carried out with colleagues Professor Vucetic, Dr. Sathiakumar, Dr. Shrivastava, and especially the Manager of the Teaching Office of the School, Miss Erica Ring who further improved the presentation of the paper.

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