

## **Introduction to Engineering: An investigation into the first year experience in an electrical engineering course**

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An introductory electrical engineering course has unintentionally become a gate-keeper course for electrical engineering students at the University of Cape Town. A phenomenographic study using course evaluation data and focus group interviews with students explored students' perceptions of structural features of the course (including work load, assessments, communication with students), students' expectations of and motivation for the course, students' approaches to studying this course, and how students experienced the pace and complexity of the content. The phenomenographical data yielded rich information about a variety of factors impacting on success in the target course. Three categories emerged: structure related factors, student related factors and disciplinary knowledge factors. This on-going study will contribute to the current re-curriculation discussion on the shape and direction of introductory engineering courses.

### **“Introduction to Engineering” Courses**

In contrast to first year courses in the basic sciences and mathematics, introductory engineering courses vary in scope, content and approach across departments and institutions (Wankat & Smith, 2012). A growing number introduce design as part of the course (Brannan & Wankat, 2005).

At the University of Cape Town (UCT), engineering students used to take the same introductory course containing generic elements common to all branches of engineering. Concerns were raised that the generality of this engineering course made it harder for students to identify with the discipline and form an identity of being an engineering-in-training. In 1995, discipline-specific “Introduction to Engineering” courses were introduced in an attempt to mitigate these concerns. The purpose of the course in each department was to expose the first year students to the terminology and techniques in their particular engineering discipline. The course content of the discipline-specific courses at UCT evolved over time. While the courses in civil and mechanical engineering have favoured project-based assessment, the chemical and electrical engineering courses have final examinations covering a substantial amount of conceptual content. The focus of the current study is the introductory course for electrical engineering students (EEE1004W).

### **Motivation for focussing on the first year electrical engineering course (EEE1004W)**

Even though the first year course is not a prerequisite for any second year courses, it is generally recognised that students who pass the course are at a distinct advantage going into second year, compared to those transferring into second year electrical engineering from other departments, faculties or universities. In spite of the initial intention of not having the course as a gatekeeper for second year, the course failure rates have been significant. Possible reasons for this are the high conceptual content of the course and the amount of ‘new’ content that does not directly link to school science.

Electrical engineering students are typical of the students accepted to study engineering at UCT: they enter with high National Senior Certificate Mathematics and Physical Science marks (respectively  $\geq 80\%$  and  $\geq 70\%$ ), and at least intermediate levels in all three of the National

Benchmark Test categories. Electrical engineering is the largest engineering department at UCT and a first year class size of around 200 is standard. Of these around 10-15% of the students join the academic support programme, ASPECT. This extended curriculum programme notionally spreads the typical four year engineering programme over five years. The EEE1004W course is a 32 credit course, comprising approximately 22% of the first year mainstream curriculum and 31% of the first year ASPECT curriculum. Students who fail the EEE1004W course are in danger of being academically excluded at the end of the year: first year mainstream students need 80 credits and ASPECT students need 64 credits to avoid exclusion. Insight into the factors that may impact on student success in EEE1004W is therefore important.

## **Research Design**

This research project has been designed to focus on what is required to succeed in the course and on the student experience of the course. For this purpose phenomenography was used as the methodological approach for the research. Phenomenography is a qualitative research approach identified by Case and Light (2011) as an emerging methodology in engineering education. It aims to provide a description of the different ways a phenomenon is experienced by a group of people. Because of this emphasis on the varied experience of a phenomenon, purposive sampling is an important aspect of the investigation.

The phenomenon of interest in this study is student performance in and experience of the EEE1004W course. The target group was a representative selection of students who completed the 2012 course with final marks ranging from below 40% to above 80%. We used semi-structured interviews in focus groups to investigate students' perceptions of the structure of the course (time-on-task, work load, types of assessment, weighting of assessments, communication with students), their expectations of and motivation towards the course, their approaches to studying this course, and how they experienced the pace and complexity of the content. In addition a course evaluation from the 2012 course was analysed. These provided the researchers with textured data sets which were analysed in a careful and iterative process to allow insights into the shared experience.

## **Data collection**

Focus group interviews were held with 20 students (5 female, 15 male) in small groups no bigger than 7 students. Fourteen students had passed the course the previous year, 7 of whom were ASPECT students. The remaining 6 were repeating the course after failing the previous year, 5 of whom were on the ASPECT programme.

An online, anonymous course evaluation completed by 115 out of 200 students (57%) mid-year in 2012 provided additional data. There were 38 items on the questionnaire out of which 32 items received a total of 405 written comments. Students were asked to give their marks on the course evaluation and this allowed us to infer that the sample was fairly representative of the class.

## **Findings**

The phenomenographical data yielded rich information about a variety of factors impacting on the student experience and success in EEE1004W. We were able to identify clusters of factors in the analysis process. These were separated into three main sections: factors relating to the structure of the course (structural factors), factors relating to students' background, expectations and motivation (student related factors), and how students perceived different sections of the course in relation to each other and to physics and mathematics (content/disciplinary knowledge factors).

## Structural factors

### *Course design factors*

The year-long course comprised two evenly-weighted sections: power and electronics, with a final examination contributing 70% of the marks. There were 4 lectures per week (2 for power and 2 for electronics) and 30 hours of laboratory sessions in the year. A design project completed in small groups contributed 10% of the final mark. All students reported that they received clear and accurate communication about the course, including the timing and weighting of assessments, the course objectives and the learning outcomes. A handout containing this information was distributed and discussed at the first class meeting and posted on the course website. This seemed to contribute towards a positive attitude towards the course at the start of the year. In the mid-year evaluation, 71% of the respondents agreed that the course is “well planned and well managed,” 20% felt neutral about this and 9% disagreed.

Despite taking mathematics, physics and computer science courses that were semesterised, no student complained about this course being a year-long course, although the high weighting of the final examination and lack of supplementary examination did cause some students anxiety. A student who was repeating the course felt “so nervous when writing” and another repeating student suggested that it was anxiety and “stressing” that makes people fail. With such a high-stakes examination, it was unfortunate that the examination timetable that year was not more conveniently spaced, with a physics examination written the day before.

Responses from the mid-year evaluation are listed in Table 1 and show students’ opinions of whether the listed learning activities were useful and coherent. For tutorials, 19% of responders disagreed and 13% felt the question was not applicable, possibly because tutorials were not weekly events as in physics or mathematics.

**Table 1.** Responses to “I believe the learning activity is useful and coherent”

	Agree (%)	Disagree / Not applicable (%)
Laboratories	84	7
Guest speakers	72	7
Lectures	63	16
Tutorials	31	32

### *Lecturers*

The electronics section was taught by a semi-retired, part-time lecturer who was a recipient of the institution’s Distinguished Teacher award. The power section was taught by two lecturers, one of whom was also the course convenor. All lecturers were seen as accessible and willing to help when consulted, either directly after a lecture, at the beginning of the day and by email arrangement, even on Saturdays.

Comments about the quality of lectures reflected diversity in students’ preferences and expectations: a lecturer could be described by some students as “clear and interesting to listen to” but by others as “boring.” Some felt intimidated by a particular lecturer’s response to “simple questions” and so refrained from ever asking questions in class, while others found the same lecturer very approachable when a clear question was asked, or found that by asking questions on email they were more likely to avoid an “irritable” reply. Difficulties with understanding accents and soft voices were reported, with suggestions of the use of a microphone. Comments on the pace of lectures indicated that some sections in electronics were rushed while for power there was overlap of some content when lecturers changed and an overuse of passive PowerPoint notes that could be read independently.

### *Tutorials and tutors*

Compared to mathematics and physics where weekly tutorials allowed for practice on the lecture content, infrequent tutorials in this course were seen as a limitation. Students appreciated weekly worksheets in the first term and suggested that handing in a task for marks was motivational and focussed attention to a subject. This was felt more in the second semester when mathematics and physics became more challenging and demanded more time.

### *Tests*

Handing out model answers to tests as students exited the test venue was highly praised as a way to get feedback on questions while they were “fresh.” No students complained about having insufficient time for tests, even though one of the interviewed students did not always complete tests. Prompts during tests to say “you should be at this point now” were appreciated. Although tests were generally considered “straightforward” there were one or two “surprising” questions in electronics, but this was seen as fair.

### *Project*

The electronics project was seen as a good platform to bring together “everything learnt in the year” and was a source of motivation for many students. The demand for students to make their own decisions about how to run the project was appreciated, even if this required going beyond the course material. A comment by one student that the in-class theory did not match what they were trying to do in the project shows that students’ expectations about gathering information for the project may not be the same as lecturers’ expectations.

### *Textbook, notes and language*

The course did not have a prescribed textbook; instead students were given comprehensive notes by each lecturer. Interestingly, none of the students with home languages other than English felt that having home-language translations of notes would have been useful. This possibly reflects the importance of proficiency in English for studies of a technical nature, one student explaining that she was “... more confident with English than my home language.” However, it was suggested that with, “tutoring in your mother tongue, a person might get it better.”

Some students felt that a textbook “might have made life easier,” providing alternative explanations, background information, more examples and a trustworthy reference when faced with errors in course notes, as they had experienced. Not being able to identify errors in the notes was a source of confusion and frustration for students. In the absence of a textbook, students dealt with errors in the notes by consulting the lecturer or by sharing ideas in study groups.

Arguments some students raised against having a textbook included the high cost and being intimidated by not knowing what parts of a large textbook are relevant compared to a well-organised set of notes. Many students felt that the notes were adequate. Alternative reference sources such as an electronic dictionary, an online textbook and a textbook that would also be used in second year were suggested by students. Where notes contain complex terms new to students, a glossary of terms “would be very helpful.”

The variety of ways that students spoke about their preferences for the different sections and different teaching approaches reflect their expectations of university teaching, which have been shaped in part by their school experiences and experiences in lectures for other courses. These will be discussed under the topic of *student related factors*.

## ***Student related factors***

### *Students' backgrounds*

The twenty students interviewed completed a short written questionnaire on their school background, where they could choose words to describe their school from a list or add their own words. The sizes of their schools were large (12) or small (4). The majority (13) described their schools as urban, 2 as rural and 1 as a "township" school. Classes had fewer than 30 students per class (12), between 30 and 40 students per class (2), or more than 40 students per class (6). One student had attended a technical high school where Electrical Technology had been a matric subject.

### *Background, expectation and motivational factors*

The challenge of managing a range of prior exposure to practical work is common to many science courses and was commented on by students with regard to the laboratory sessions for EEE1004W. The student who had attended a technical school felt "cheated" by having to perform laboratory work that was familiar while already able to do what the second year students were doing in their practical work. Others who had never built a circuit felt they were expected to start the course with knowledge they didn't have.

There was evidence of the different sections shaping students' perceptions about the course, for example it was considered "alright" to be just passing because electronics was considered difficult to master, even when considerable effort was devoted to it. The mid-year course evaluation showed that the majority of students were coping with the demands of the course: 75% agreed that the workload for the course was manageable and 70% agreed that the level of difficulty for the course was correct.

Exposure to both power and electronics confirmed for some students their choice of programme (mechatronics, electrical and computer engineering and electrical engineering) and encouraged others to change their programme, both towards and away from electronics-focussed specialities. Interestingly, the number of students in the senior courses of the electronics-rich mechatronics programme has grown in the past few years to be significantly larger than the other two programmes. The factors around this have not been explored but it suggests that students are not put off electronics in first year, even when they find it challenging.

## ***Course content / disciplinary knowledge factors***

### *Relating to the different sections of the course: electronics and power*

The weighting of the different sections was seen by some as disproportionate to the relative difficulty of the sections. Many concepts in power were familiar from school and were easy to grasp whereas electronics was unfamiliar and difficult. The contrast was emphasised by having both power and electronics lectures every week, causing some students to question the time allocations for the sections.

The teaching approaches to the electronics and power sections reflected the teaching styles of the different lecturers. The electronics section emphasised application and students reported that they were challenged with questions in class whereas the power section tended to be less demanding of students. Of the power lectures, one student said, "If it was something I could do myself at home, there wasn't much point in coming to class." Some of the familiarity with the power topics in the course may be the result of some overlap with topics in the Physics for Engineers course.

A high-performing student realised the different natures of the sections but critiqued the power section for only covering "general, surface knowledge" and the electronics section for not

having “more practical parts incorporated, more labs.” This was in spite of the significantly larger number of electronics practical sessions: there were 3 times as many laboratory sessions for electronics than for power.

Some students were advised by their senior-year mentors to focus on both sections and not let one side “drop”, yet this was precisely what some students experienced. Students made strategic decisions: some neglected electronics in favour of power because they “would pass if you know your power.” Others spent longer on electronics during preparation and tests because it took longer to understand the concepts. This raises the issue of how to assist students in managing the time spent on the different sections.

### *Characterising engineering science knowledge as distinct from physics knowledge*

In a classical paper on disciplinary differences in the way academic departments at universities are organised around subject matter, Biglan (1973) proposes a double set of binaries to describe different disciplines. In the first place he makes a distinction between ‘hard’ and ‘soft’ disciplines: ‘hard’ disciplines are ones with general consensus around the theory (what is known), and what constitutes suitable methods to investigate problems appropriate to the discipline. The sciences are typical ‘hard’ disciplines. Secondly, he distinguishes between ‘pure’ and ‘applied’ disciplines. In the ‘pure’ disciplines there is much less of a concern about the application of theoretical knowledge. According to this binary classification the engineering science in EEE1004W would be classified as a ‘hard-applied’ discipline, whereas the physics knowledge which students meet in their physics course would be seen as a ‘hard-pure’ discipline. Muller (2009) tells us that disciplinary structure impacts on curriculum, and we were interested to see whether novice students picked up on some of these differences in the disciplines. When asked to compare ways of thinking in the electrical engineering course with mathematics or physics courses, students focused on the power section in EEE1004W and the section on electricity done in physics. Although there was content overlap in these sections in the form of equations commonly used in both power and electricity, students were able to distinguish ways of thinking that typified the discipline. Physics was seen as “classical,” where equations were derived from fundamentals, and the focus was on “what happened inside the wires.” By contrast, in engineering the fundamentals were assumed and equations were seen as “tools to get you somewhere.” The sense was that in engineering, “design is the main thing” and the focus on applications is to get you to see “how the whole works.” The interest in how components function may have underpinned a comment that “electronics is more abstract.”

### **Discussion and conclusion**

Despite workshops and lecturer recommendations on preparation for examinations, some students were affected by the anxiety provoked by a high stakes examination. This suggests to a need to help students manage themselves in a way that reduces pre-examination anxiety. Institutional practices that can help reduce student anxiety include scheduling well-spaced examinations and second-chance supplementary examinations for students who fail by a small margin. The current policy of the Faculty of Engineering and the Built Environment at UCT is not to offer supplementary examinations in engineering courses.

The technical difficulty of struggling to hear lecturers is a feature that may disproportionately affect multi-lingual students who are less familiar with English. Even lecturers who feel that their voice is sufficiently loud might do well to consider using a microphone for the benefit of students who already have to engage with the language in a different way to home-language English speakers.

Providing for a range of abilities and preferred approaches to learning (Fry, Ketteridge & Marshall, 2009:18) is a challenge, particularly in a large class. Using a variety of teaching approaches can distribute the advantage of being taught in a preferred style to more students. It

may be worthwhile to alert students to the variety of expectations students and lecturers have regarding what is the most effective way to learn. Students who feel they are not coping could be directed to alternative learning strategies they may not have used before.

Activities to cater for students who have never used a laboratory before included two orientation laboratory sessions, soldering workshops and regular opportunities for 'catch-up labs' for students unable to complete in the regular laboratory time. Despite attending these, some students felt that they were expected to have more practical skills than they had, suggesting a focus on middle range students by lecturers. To cater for students with more experience, such as those who completed Electrical Technology at school, credit could be given for certain laboratory sessions.

Some practical recommendations for improving the student experience on the course could be recruiting tutors able to give explanations in different languages, giving references to other sources (books, websites) for students who want alternative explanations and who prefer learning by reading outside of lectures; and compiling a glossary of terms to help students when reading notes with many new terms.

The combination of using focus-group interviews together with traditional course evaluations was valuable in gaining a deeper understanding the students' perceptions of the course. These methods were particularly useful for a group of students characterised by diversity.

We envisage that this study will contribute to the current discussion on the shape and direction of the Introduction to Engineering courses in the light of curriculum review currently under way in the Faculty of Engineering and the Built Environment at the University of Cape Town and potentially lead to more students achieving competency in the outcomes of the course.

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