AC 2008-258: THE TRANSITION FROM HIGH-SCHOOL PHYSICS TO FIRST-YEAR ELECTRICAL ENGINEERING: HOW WELL PREPARED ARE OUR STUDENTS?

Chris Smaill, University of Auckland

Chris Smaill holds a Ph.D. in engineering education from Curtin University of Technology, Australia, and degrees in physics, mathematics and philosophy from the University of Auckland. For 27 years he taught physics and mathematics at high school level, most recently as Head of Physics at Rangitoto College, New Zealand's largest secondary school. This period also saw him setting and marking national examinations, training high-school teachers, and publishing several physics texts. Since the start of 2002 he has lectured in the Department of Electrical & Computer Engineering at the University of Auckland.

Elizabeth Godfrey, University of Auckland

Elizabeth Godfrey is currently the Associate Dean Undergraduate at the School of Engineering at the University of Auckland after a career that has included university lecturing, teaching and 10 years as an advocate for Women in Science and Engineering. She has been a contributor to Engineering Education conferences, and an advocate for the Scholarship of Teaching and Learning since the early 1990s, and is currently a member of the Australasian Association of Engineering Education executive.

Gerard Rowe, University of Auckland

Gerard Rowe completed the degrees of BE, ME and PhD at the University of Auckland in 1978, 1980 and 1984 respectively. He joined the Department of Electrical and Computer Engineering at the University of Auckland in 1984 where he is currently a Senior Lecturer. He is a member of the Department's Radio Systems Group and his (disciplinary) research interests lie in the areas of radio systems, electromagnetics and bioelectromagnetics. Over the last 20 years he has taught at all levels and has developed a particular interest in curriculum and course design. He has received numerous teaching awards from his institution. In 2004 he was awarded a (National) Tertiary Teaching Excellence Award in the Sustained Excellence in Teaching category and in 2005 he received the Australasian Association for Engineering Education award for excellence in Engineering Education in the Teaching and Learning category. Dr Rowe is a member of the IET, the IEEE, the Institution of Professional Engineers of New Zealand (IPENZ), ASEE, STLHE and AaeE.

The transition from high-school Physics to first-year Electrical Engineering: How well prepared are our students?

Abstract

The demand from industry for an increasing number of engineering graduates in New Zealand reflects international concerns and is compounded by a decrease in the size of the well-prepared school-leaver pool. For growth in graduate numbers to occur, it is recognized that a more diverse, potentially less-well-prepared student cohort will challenge engineering educators to respond effectively via curriculum, assessment and teaching methods to optimize success and retention at first year.

A preliminary evaluation of the first (2007) cycle of a two-cycle action-research project is presented in this paper. This project aims to identify the level of preparedness the student cohort brings to a year-one course in Electrical and Digital Systems, to determine key factors that lead to success in this course, to measure the effectiveness of remedial and support mechanisms, and to audit the content and assessment of the course itself. The course, compulsory for all first-year engineering students has long been perceived as "difficult", with a higher fail rate than other first-year courses, and somewhat of a "gatekeeper" for passage to the discipline-specific final three years.

Introduction

Despite New Zealand's reputation for innovative technology and its status as a developed country with a relatively high standard of living, amongst the OECD countries it has the lowest proportion of its university graduates in engineering. A potential mismatch exists between the increase in the number of engineering graduates demanded by industry and the profession [1] and the decrease in the number of final-year high-school students studying physics and other engineering-specific pre-requisite subjects.

The low proportion of engineering graduates might be viewed as a local problem, but it echoes the situation in much larger, more industrialized, and resource-rich countries such as the United States. The sharp increase over the last 15 years in research investigating academic success and persistence within engineering programs has been identified by French, Immekus and Oakes [2], as being linked to a declining interest in engineering amongst graduating high-school students and low completion rates by students entering US universities as engineering majors. The freshman (first) year has been seen as critical [3] for both academic success and retention of engineering students.

From the student "voices" provided by Seymour and Hewitt [4], to the indicators of success and persistence based on theoretical and empirical evidence from both cognitive and non-cognitive variables [2], a wealth of data has been accumulated to guide curriculum design and program development.

It is known that strong academic background, achievement of good grades, and academic motivation are needed for students to persist in their engineering studies. If, as it has been suggested, "the only significant predictor of graduation with an engineering degree was high-school GPA" [5], then efforts to enlarge the potential pool of applicants will be severely challenged. It is recognized that if engineering educators are to respond to industry calls for an increased number of engineering graduates, a large portion of that increase is likely to come from a more diverse range of students, including currently under-represented ethnic groups and women, as well as students with lower entry-level qualifications in mathematics and physics. It is also recognized that while these students may initially struggle academically they may well have the potential and motivation to make a significant contribution to the engineering profession, provided appropriate academic and social support systems, remedial and "catch-up" courses are provided.

For first-year or freshman courses, the diversity of students' academic backgrounds is an ongoing challenge, particularly in courses where a level of pre-requisite knowledge is assumed. In New Zealand, one national qualification for University Entrance was the norm for many years, providing some measure of surety about levels of pre-requisite knowledge based on common curricula. The current situation, with a recently–introduced, modular and criteria-based national qualification that has been the subject of much debate[6], is challenging previous assumptions about the commonality of prior knowledge. The dual objectives of identifying students with the ability to succeed in engineering, and ensuring their academic success and retention to graduation were the motivation for the project from which findings for this paper were drawn.

The Electrical Engineering course ELECTENG101, compulsory for all first-year engineering students at the University of Auckland, has been perceived as "difficult" and somewhat of a gatekeeper in the passage to the discipline-specific final three years of the undergraduate degree. Pass rates (as shown later in the paper) were consistently lower than in other year-one courses, particularly for under-represented groups such as Maori, Pacific Island and women students, despite the course being taught by well-motivated and experienced lecturers who have an interest in the scholarship of teaching and use innovative technology and assessment methods. Given that the engineering degree has the highest average entry qualification for any degree at this top-ranked university, and given also that the course has clearly identifiable pre-requisite knowledge, the situation was ripe for investigation.

The overall goal of the research project, from which this paper is drawn, is to maximize the achievement of the students enrolled in the compulsory first-year electrical engineering course, "Electrical and Digital Systems" (ELECTENG101). It was seen as essential to identify the academic preparedness of students for their first-year studies in order to enable the curriculum, assessment and teaching methods to respond effectively, but it had also been perceived that new and more diverse entry qualifications introduced over the last few years had made this identification task much more difficult. Recent government moves to "cap" student enrolments at universities to provide some surety in government spending have also increased the importance of student recruitment, selection and retention.

Specifically, this research study aims to identify the level of preparedness the year-one cohort brings to ELECTENG101, to determine key factors that lead to success in this course, to measure the effectiveness of remedial and support mechanisms, and to audit the content and assessment of the course itself. Specific objectives include:

- To analyze the educational background of the students in ELECTENG101, particularly relating to physics. The majority of the students currently have one of three distinct qualifications, and subject data is available for these. The qualifications are: National Certificate of Educational Achievement (NCEA - details available at http://www.nzqa.govt.nz/ncea/), Cambridge International Examination (CIE - details available at http://www.cie.org.uk/), and International Baccalaureate (IB - details available at http://www.ibo.org/).

- To determine the educational achievement and learning outcomes of the students in ELECTENG101. Analysis of assignment, test and examination results will be supplemented with semi-structured interviews to reveal the "how" and "why" of this achievement.
- To search for patterns and correlations between the high-school educational backgrounds of the students, the results of diagnostic tests measuring concept mastery, and their achievements in the year-one course.
- To pursue two cycles of action research in which the effects of changes implemented after the first cycle are investigated.
- To set precedents for methodology and data analysis that will contribute to the wider analysis of the first-year experience in engineering. It is envisaged that the findings from this research will inform appropriate modifications to other first-year engineering courses, and the initiation of targeted "catch-up" courses and ongoing support where appropriate.

Current selection methods and criteria from high school qualifications are examined as predictors of academic success. The results of a diagnostic assessment completed in the first week, including both item analysis and student interviews, provided findings which were constructive for course delivery, both in teaching and assessment methods. Feedback from current students and focus-group discussions with high-school Physics teachers affirmed these findings. The impact of the reflection by both staff and students caused by the use of diagnostic instruments, appears to be evidenced in the analysis of the 2007 examination results for this course with significant improvements in learning outcomes.

Suggestions for improvement to the delivery of the 2008 course will be outlined together with identification of areas requiring further investigation in the second action-research cycle.

The next section provides the context of this research study with a brief summary of information about the university, the engineering degree structure, the course itself, the diversity of the student cohort and some recruitment and retention data. The Methodology and specific objectives of the project are then followed by an analysis of the findings from the first research cycle. Recommendations for the second cycle of research are presented together with our conclusions.

Context

The University of Auckland is the top-ranked university, internationally, in New Zealand (top 50 in the Times Higher Education World University Rankings, available at http://www.timeshighereducation.co.uk/). It also has the largest Faculty of Engineering in the country. The approximately 2300 undergraduate students are divided across nine engineering specializations for a four-year Bachelor of Engineering Honours degree. All undergraduate students, except a small core of accelerated students, do a common first year of seven engineering courses, all taught in-house in an engineering context. Because applications exceed the allowed number of places (620 including international students) by a factor of more than 3:1, selection is necessary at first-year level. This does allow the luxury of selecting for a background that includes some strength in mathematics and physics. It is recognized that some of the academic diversity likely to be present in the more usual "open" entry, science-based first-year programs of other universities is removed by this selection process. Decreasing numbers of high-school students studying physics, combined with demographic trends have, however, resulted in a perceived decrease in "quality" and quantity in the applicant pool.

With high demand for places, and selection occurring at this first-year level, retention is not so critical an issue as has been reported in many overseas universities. Approximately 10% of each year's intake does not return to engineering after the first year.

ELECTENG101 is one of the compulsory core papers for all first-year engineering undergraduates. The others are Mathematical Modelling, Engineering Mechanics, Engineering Design, Biology and Chemistry for Engineers, Engineering Computation and Software Development, and Materials Science. Selection and study in a specific engineering discipline is not undertaken until all first-year courses are completed.

Methodology

An action-research methodology seemed appropriate for an iterative, reflective process that would allow for inquiry and discussion as components of the "research". Commonly those who apply an action-research approach are practitioners who wish to improve understanding of their own practice. Although the naming and number of the steps involved can vary, action research always involves a series of cycles, sometimes envisioned as a spiral [7]. Initially, a problem is identified, action is planned and implemented, then the results are evaluated and reflection occurs. The insights gained from the initial cycle feed into the planning of the second cycle, for which the action plan is modified and the research process repeated, as illustrated in Figure 1.

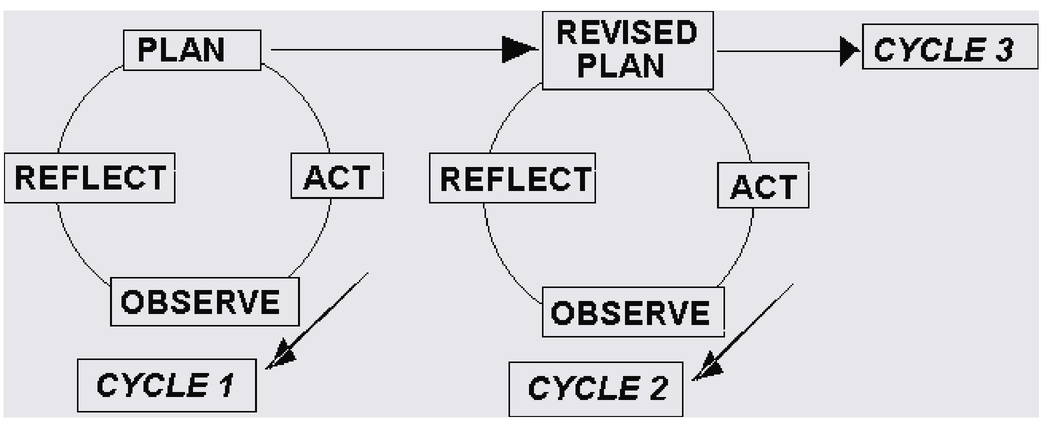


Figure 1. The action-research process from Riding, Fowell and Levy [7]

The aims of the first action cycle (whose results form the basis of this paper) were to investigate the level of preparedness that the student cohort brings to a year-one course in Electrical and Digital Systems, to determine key factors that lead to success in this course and to measure the effectiveness of remedial and support mechanisms.

Student entry-level preparedness was investigated by analysis of their high-school examination results, administration of a diagnostic test, follow-up interviews with students, and focus-group interviews with high-school physics teachers. The key factors that lead to success in this course were investigated by correlating high-school examination results with ELECTENG101 examination results and by interviewing students following the final examination. The effectiveness of remedial and support mechanisms was investigated by examining historical and current course examination results and via post-examination student interviews.

Findings

Entry Level Preparedness

The first year cohort in 2007 was composed of 590 new students of whom 76% were school leavers and 16% had transferred from preliminary science studies within the university. The balance was from a wide range of backgrounds including university and technician level qualifications. Of the students arriving directly from high school 57% had qualified for entry via the National Certificate of Educational Achievement (NCEA) Level 3 examinations, 17.7% via Cambridge International Exams (CIE) and 2% via International Baccalaureate (IB). For the (second-semester) course ELECTENG101 (comprising 609 students), 39 students were repeating the course.

Part of the investigation into the educational background of the students entailed an analysis of their high-school examination results. For example, in the case of those students who sat the NCEA Level 3 examinations, this involved determining which achievement standards they achieved, their grades in these standards, and the overall national distribution of grades in the standards year-by-year. Similar sorts of analyses were carried out for those students who sat the CIE or the IB. For reasons of brevity only NCEA results are considered in detail in this paper.

Each NCEA subject has a maximum of 24 credits available in several separate modules. In the case of final-year (Level 3), high-school physics, there are five modules, of which four are assessed by national external examinations. The NCEA examination provides no ranking score. Instead, achievement for each module attempted is simply graded as Not Achieved (N), Achieved (A), Merit (M) or Excellent (E). For entry selection purposes, the University of Auckland devised, and has used for three years, a ranking score which takes account of both the quality and the quantity of the credits obtained. A histogram of the 2007 entry cohort's Electrical module achievements is presented in Figure 2. A worrying feature of this histogram is the high percentage of the class that have either a bare pass (A) or have failed to achieve a pass (N) in the Electrical module.

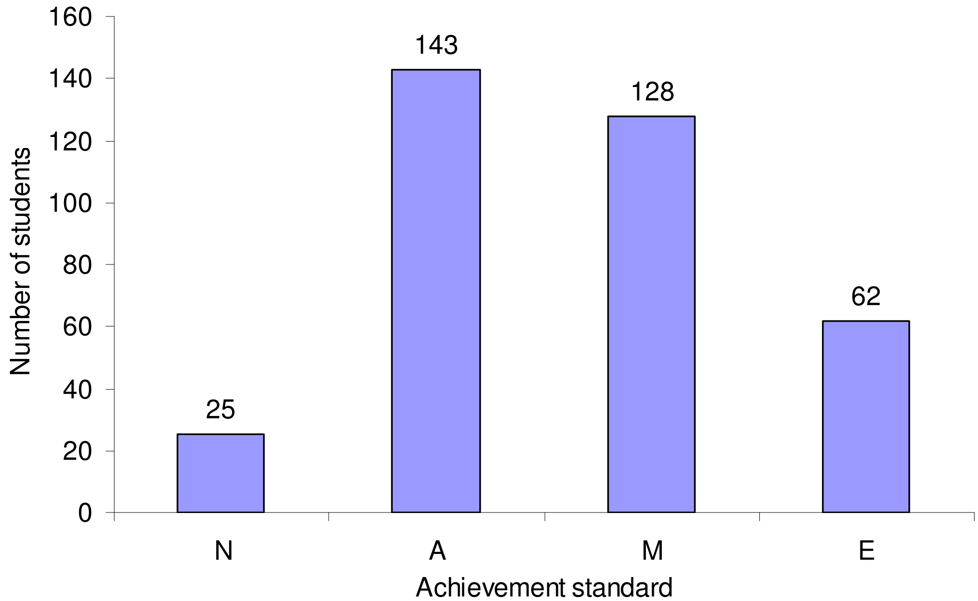


Figure 2. Achievement of the 2007 cohort in the NCEA Electrical module

As a further step in gathering information about the student's level of preparedness, a diagnostic assessment was administered (without prior warning) on the second day of the ELECTENG101 course. This 30-minute assessment consisted of 22 questions. The first 20 questions were multiple-choice while the final two questions were free-response questions. The 20 multiple-choice questions (worth 1 mark each) covered simple circuit theory (involving batteries, switches, light bulbs and resistors), forces exerted on charges and currents in magnetic fields, and electromagnetic induction – and were taken from NCEA Level-3 resource material and high-school Physics concept inventories. The first free-response question addressed simple circuit analysis (worth 3 marks) while the second addressed simple algebraic manipulation (worth 2 marks). These two free-response questions were marked either right (full marks) or wrong (zero marks).

A total of 560 students completed the 22-question test. The test invigilators reported that the 30 minutes allocated to the test appeared to be ample, as a significant number of students appeared to finish with adequate time to spare. The students also appeared to take the test seriously, as evidenced by the fact that they did spend most of the allocated 30 minutes working on their answers, and by the amount they wrote in answering the free-response questions. A mark histogram is provided in Figure 3.

The average mark was 10.4 out of 25, with 55 students (9.8%) scoring 5 or under. For the 20 multiple-choice questions (Q1-Q20) the average was about 9 out of 20. In the case of the free-response questions, Q21 (year-12 electric circuit theory) was correctly answered by only 11% of the students, while Q22 (year-11 mathematics) was correctly answered by 60% of the students. (Here it should be noted that year-13 is the final year of high-school education in New Zealand.)

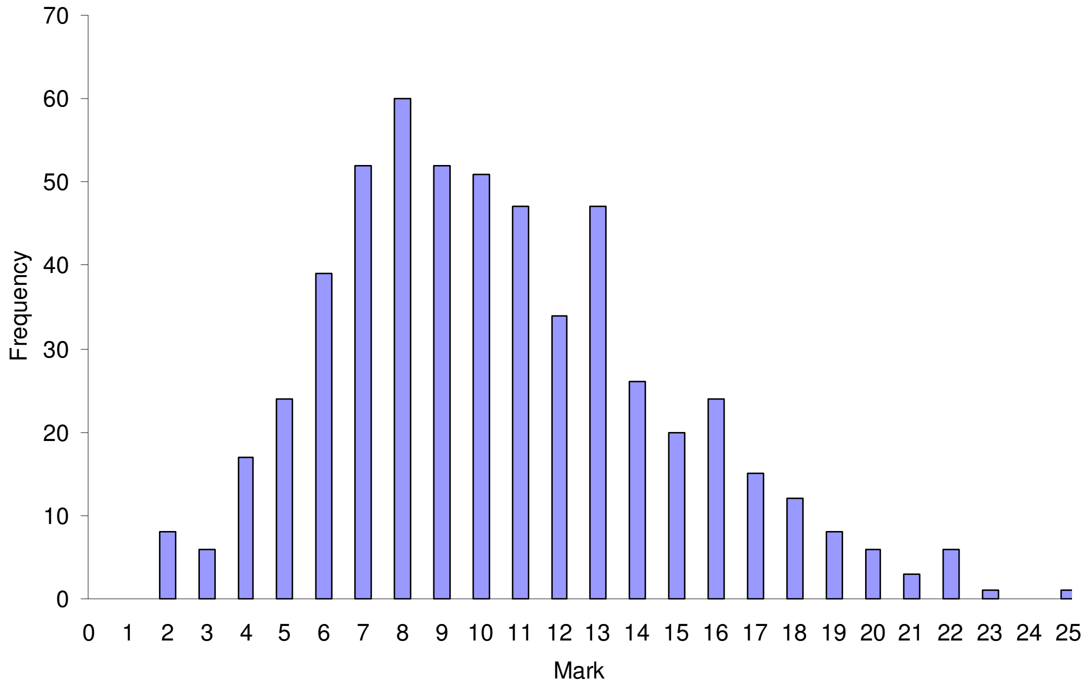


Figure 3. Mark histogram for 2007 diagnostic test

The results were clearly very disappointing. They appeared to indicate that most of the class either had not understood or had forgotten much of the basic physics they had covered in high school.

To enable better interpretation of these results, a number of class members were interviewed, in either focus-group sessions or individual interviews, during weeks five and six of the semester. The interviews were conducted by one of the authors (who was not involved in teaching the class and was unknown to the students). The interviews used the diagnostic test as a basis and largely consisted of open-ended questions that asked the students to explain their thinking processes in answering the various questions. The interviews were audio-recorded and later transcribed, with these records being used to supplement notes taken by the interviewer. When students sit a diagnostic test, the score for which has no effect on their class grade, it is inevitable that some fraction will devote little effort to answering the questions. When selecting students for interview we deliberately did not select any whose diagnostic test score was equal to or below the random guessing score of 4.6. This is consistent with the approach followed by Steif and Hansen[8]. Similarly, since we wished to probe conceptual misunderstandings, we chose not to interview students with diagnostic test scores of 14 or higher. The students invited to the interviews thus all scored marks in the range 5 to13 out of 25.

In the interviews[9], the students indicated the following:

- Sufficient time was allowed for the test.
- The class did make a genuine effort in answering the test questions. However, the students were not unduly troubled by their results as the test did not count toward their final course grade.
- The students were surprised at how much they had forgotten. They reported that many of their peers realized they had not done very well.

- Specific ad-hoc rules had often been taught in high schools for generators while other rules had been taught for motors. When asked to identify difficulties encountered in answering the diagnostic test, one student commented *"...just trying to remember the hand rules - left hand and right hand. You just know left hand for electrons and right hand for current"*. By contrast, the unified approach for motional electromotive force (emf) taught in ELECTENG 101 that used right-handed coordinate systems and conventional current were seen as preferable: *"What we are learning now....everything in the right hand...it's good to have that."*
- The students commented on differences in topic coverage and depth of coverage across the various entrance qualifications of NCEA, CIE and IB. They saw this as an issue that might explain misconceptions students exhibited on parts of the diagnostic test.

Subsequent review of the interviewer's notes and of the interview transcriptions highlighted a student learning approach that could best be described as "bitsy" rather than unified. A possible explanation for this approach is that the recent introduction of the achievement-standards-based NCEA qualification in New Zealand high schools has led to teachers adopting a more modular teaching style which, in turn, has encouraged students to adopt a more fragmented approach to their learning.

The final step in the cycle-1 investigation of entry-level preparedness was focus-group interviews with physics teachers. An experienced group of 105 high-school physics teachers participated in a focus-group discussion and also provided written responses to a questionnaire. The key results of the teacher focus groups were:

- Instrumentalist approach to study and module choices.
- High demand for accountability in marking schedules.
- Studying to a perceived "expected answer".
- Confirmation that NCEA had resulted in a more modular (i.e. less integrated) approach to learning.
- Identification that the new NCEA Physics Curriculum places less reliance on mathematical ability. It was now not possible to achieve a pass in an NCEA module without being able to adequately answer "explain" type questions. This represents a major departure from previous curricular practice.

Predictors of Success

The key factors that lead to success in this course were investigated by correlating high-school examination results with ELECTENG101 examination results and by interviewing students following the final examination.

For reasons of brevity, only those who entered directly from school with an NCEA ranked score are included in this part of the analysis. Care must be taken in interpreting the results as those students who achieved a low NCEA ranked score were required to take first-year university courses in Maths and Physics to strengthen their background prior to enrolling in engineering and are therefore not included in this analysis. Two facets of the entry cohort's NCEA scores were correlated with ELECTENG101 examination results, namely the overall NCEA ranked score achieved and the achievement level in the NCEA Electrical module.

Predictive ability of NCEA ranked score

The ELECTENG101 mark is plotted against the NCEA ranked score in Figure 4. The maximum possible NCEA ranked score is 320 while enrolment selection policy precluded enrolment of students with an NCEA ranked score lower than 170. Analysis shows that the NCEA ranked score exhibited a correlation of 0.57 with the final ELECTENG101 result. This implies a strong relationship between these two variables, although the figure also shows considerable variability for low- and mid-range NCEA scores. In particular, it should be noted that the 85 students whose entry score was below the dotted line in the graph below were initially considered "at risk" of failing the course. These students gained ELECTENG101 marks ranging between 22 and 89% - clearly demonstrating that their entry scores did not provide a complete picture of their ability to succeed. The current analysis has not explored their (individual) use of support or remedial assistance, or their level of study skills and commitment. The next cycle of research will endeavour to make a more in-depth study of these factors.

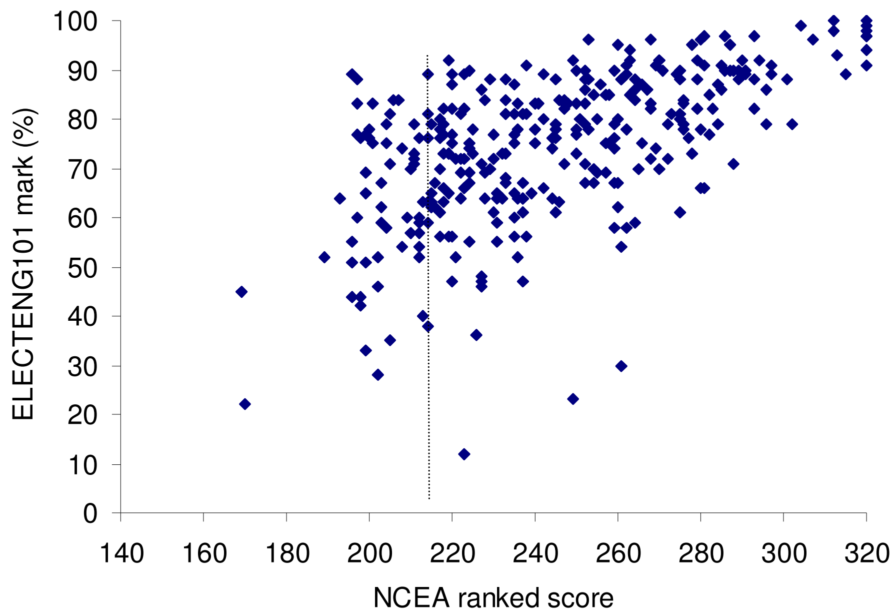


Figure 4. ELECTENG101 mark vs. NCEA ranked score

Predictive ability of achievement in the Electrical module

When interviewing students whose overall ranked score was near the borderline for entry, the grades received for the Mechanics and Electrical modules within the Physics subject for NCEA were considered as possible indicators of likely success in first-year engineering. The weighting given in the overall score had been 0 for Not Achieved, 2 for Achieved, 3 for Merit and 4 for Excellent. Analysis determined a correlation coefficient of 0.40 for the correlation between the score in the Electrical module and the final ELECTENG101 result, implying that the grade in this module does provide some indication of likely success but, as evidenced in the scatter diagram below (Figure 5), there was considerable variation.

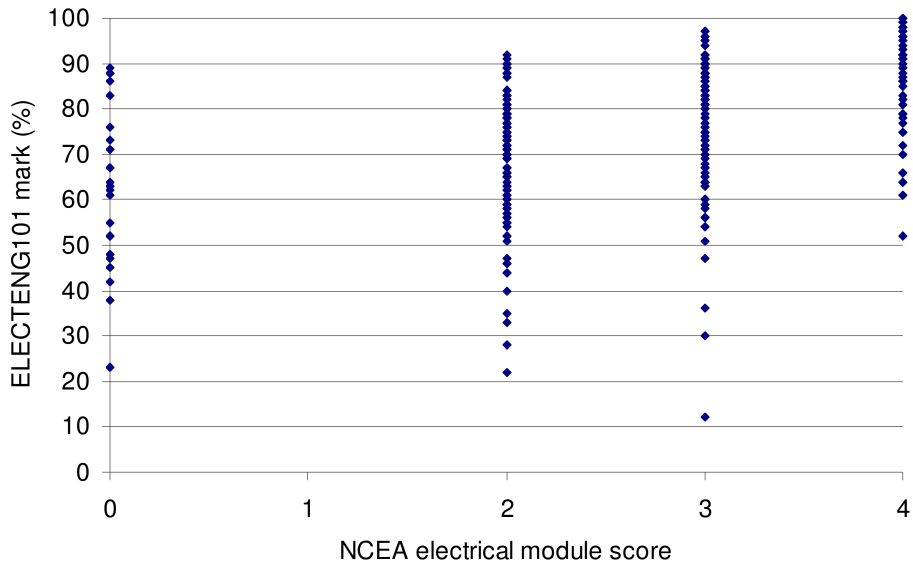


Figure 5. Correlation between ELECTENG101 mark and NCEA electrical module score

Of particular relevance for the formulation of entry-selection policy was the clear evidence that a significant number of students who had not achieved in the electrical module, or who had chosen not to attempt the module's examination, were still able to achieve passing grades at university level.

The predictive ability of the Cambridge International Examinations, commonly known as "A" levels, was also explored for both local and international students. Generally the New Zealand students who pursue this qualification rather than NCEA do so by choice, and the distribution of their marks was found to be skewed, perhaps as a consequence of extra motivation. The UCAS tariff, which is the measure used to discriminate between CIE candidates, is a somewhat "chunky" variable and is deceptive as a ranking measure. All students had a tariff between 360 (score of AAA) and 280 (score of BBC) in multiples of 10. It should also be recognized that applicants can present with subjects at either A2 level (2 years of study) and AS level (1 year of study). For New Zealand students the correlation between their tariff score and their ELECTENG101 result was 0.49 (for n=43) implying (as noted by Shulruf, Hattie and Tumen [10]) that CIE as a predictor of first-year success was less reliable than the NCEA ranked score. For International CIE students, who sit the same examinations, there was a higher correlation coefficient of 0.53. However, in interpreting this result it needs to be recognized that the majority of these students sit the examinations as scholarship students in a highly-focussed pre-university program and are required complete full A2 study in Mathematics and Physics.

Gender as a predictor of success

Electrical Engineering has had one of the lowest discipline-specific female participation rates internationally[11], possibly giving rise to the perception that female students have difficulty with this subject. Evidence from previous research[12], using the Cohen d "effect size" to examine gender differences in this course, did not support this perception. Ten years after that research the situation appears to be largely unchanged. Although NCEA was the incoming qualification for only about 57% of the ELECTENG101 class, when using that group to explore potential differences in entering qualification it was found that the calculated effect size for gender was only d = 0.01, almost zero, implying no gender difference based on entering qualification.

However diagnostic test scores for the whole class gave an effect size of d= 0.485 which may be described as medium, and of practical significance. This would imply a significant difference in the level of understanding of electrical principles and their application at the time of the diagnostic test.

Notably, the final results for ELECTENG101 showed a minimal gender difference with an effect size of only 0.185. Without trying to make too big a leap in the implications of these statistics it would appear that there was no gender difference by the end of the course. Gender cannot therefore be considered as a predictor of success or failure for this course.

Student interviews

Interviews with students conducted after the final examination focussed on the meaning and understandings that students had in relation to their study, the subject itself and concepts within the subject. It was hoped that perceived barriers (to successful high-school to university transition) would be identified by this methodology.

All interviewees judged the ELECTENG101 course to be well organized. The majority considered that the course was popular with students (even non-electrical majors), in agreement with the positive ratings achieved in the formal end-of-course class survey. Variations in content and depth of coverage between the various entrance qualifications (NCEA, CIE and IB) were identified by students as an issue. In addition, the modular assessment approach adopted by NCEA was identified by some interviewees as hindering an integrated understanding of subject matter. By contrast, the consistent unified approach taught at university was seen as preferable. As an example, one of the student interviewees commented:

> *"I personally think it was a lot clearer at university. I found the left and right (hand rules) quite confusing at school and it makes a lot more sense to use the cross product."*

The use of ad-hoc rules for the treatment of physical phenomena (e.g. specific instances of motional electromotive force (emf)) also appeared to be an impediment to learning. Circuit theory and motional emf were identified in interviews as areas where misconceptions were pronounced, while the material on operational amplifiers and transistors was perceived as both new and difficult, but an enjoyable challenge. The most significant finding from the student interviews was the extent to which students adopted a strategic approach to their study for high-school examinations. In particular, they tended to be very selective in allocating their efforts to the modules: interviewees who had already decided not to major in Electrical Engineering reported putting less examination study effort into the NCEA Electrical module. One interviewee reported deciding not to even attempt the Electrical module. These students still did, however, attend the classes for the NCEA Electrical module. This approach may explain why students with low NCEA Electrical module scores (Figure 5) were nevertheless still able to comfortably pass the ELECTENG101 examination. In fact, enrolment and participation in the NCEA Electrical module may be a better predictor of success for low-achieving students than their actual module score.

The effectiveness of remedial and support mechanisms

The most significant ELECTENG101 course change between 2006 and 2007 (i.e. during Cycle 1) was the introduction of a diagnostic test and minor modifications to tutorial material and the pace of lectures as a consequence of misunderstandings identified by that diagnostic test. Examination results for 2006 and 2007 were compared to identify any differences. The results are presented in Table 1.

Year	Final Exam Pass Rate	Final Pass Rate (Includes coursework and scaling.)
2006	64.8%	85.8%
2007	81%	93.8%

Table 1. Comparison of 2006 and 2007 ELECTENG101 results.

These results raise an obvious question: is the increased pass rate significant? Using the final examination pass rates for 2006 and 2007 yields an effect size of d = 0.61. On this basis the implication that there was a significant difference in performance between the two years is quite strong.

The possible explanations needing investigation are:
- Were the students brighter in 2007?
- Were the marking schedule or the level of difficulty of the examination questions different in 2007?
- Was there an unconscious effort (on the part of the lecturers) to bend to pressure to increase the proportion of passing students?

Relative cohort abilities

The relative abilities of the 2006 and 2007 cohorts were compared on the basis of their average NCEA ranked score. The details are presented in Table 2.

Year	Average NCEA Ranked Score	Standard Deviation	Sample Size (n)
2006	249.6	32.1	302
2007	243.7	31.7	325

Table 2. Comparison of 2006 and 2007 Cohort Abilities.

These results clearly do not support the hypothesis that the 2007 cohort had a significantly higher ability than the 2006 cohort. In fact, the effect size difference between the two entering groups was d = 0.18 – i.e. very small and positive, suggesting, if anything, that the 2006 cohort was slightly more able on average than the 2007 cohort.

Relative Examination Difficulty

Analysis of the 2006 and 2007 examinations on a question-by-question basis revealed that while the students performed significantly better in the examination in 2007, there were in fact no major changes in style in the examination questions. The questions were of graduated levels of difficulty, concentrating in the main on the first four levels of Bloom's Taxonomy, namely Knowledge, Comprehension, Application and Analysis. Nevertheless, the question-by-question histograms do show major differences in mark distribution between the two years, perhaps pointing to either better understanding achieved by the students in the 2007 cohort or a modified marking schedule for the examination questions or some combination of both of these.

Further evidence for improved achievement of learning outcomes within the 2007 cohort was provided by revisiting three questions from the diagnostic test in the final examination. The results are outlined below.

Q9 from the diagnostic test became Q3 (c) in the final exam. This question is reproduced below.

What is the potential difference between points A and B?

(A) 0 V
(B) 3 V
(C) 6 V
(D) 12 V

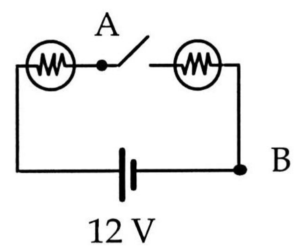
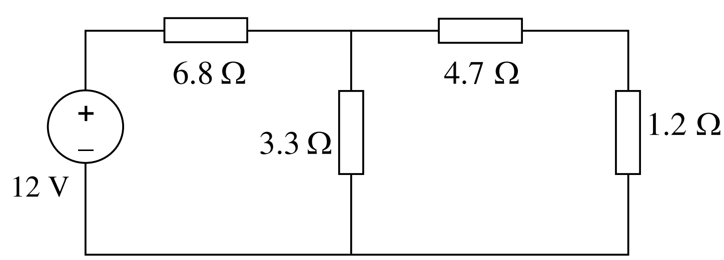


Figure 6: Diagnostic Test Question 9.

In the diagnostic test 25% of the students answered the question correctly. This is extremely worrying, since this figure would be achieved if every student simply guessed the answer. In the final examination 42% of the students answered the question correctly. While this represents a significant improvement it does still give cause for concern.

Q21 from the diagnostic test became, with values changed, Q3 (f) in the final exam. The diagnostic test question is reproduced below.



The diagram above shows four resistances connected to a voltage source. Find the current in the 1.2 Ω resistance.

Figure 7: Diagnostic Test Question 21.

In the diagnostic test a mere 11% of the students answered the question (based on high-school year-12 physics) correctly. In the final exam 78% of the students answered the question correctly. Following the diagnostic test, in the wake of the very low percentage of students who answered the question correctly, tutors were asked to go over this question in the week-two tutorial. In addition, OASIS [13] (an on-line skills-based practice tool used in this course) also contained this question and others like it for student practice.

Q22 from the diagnostic test became part of Q3 (g) in the final examination. The diagnostic test question is reproduced below.

Solve for *V*: $$\frac{V}{6}+\frac{V-3}{4}+\frac{V+5}{3}+2=0$$

In the diagnostic test 60% of the students answered the question (based on high school year-11 mathematics) correctly. The final examination question required students to analyze a circuit. The first step in the analysis was to derive an equation similar to that above. The second step was to solve the equation. 85% of the students could derive the equation and, of these, 94% correctly solved it. One lecture was spent on the circuit analysis technique and in the course of this lecture three equations like the one given above were solved. Students were also given textbook, tutorial and OASIS problems that required them to solve such equations.

It does seem that the poor results in the diagnostic test served as a “wake-up call” for the students. In addition, modifications to course presentation to “plug the gaps” identified by the diagnostic test seem to have improved student understanding.

Discussions were held with the ELECTENG101 course lecturers re changes to lecturing approach, marking schedule, selection of assessment items and operation of the supporting tutorial system. Apart from the previously-discussed changes to tutorials and minor modifications to course presentation (in light of the diagnostic test results), no major changes were made in regard to selection of examination assessment items or to devising the examination marking schedule. However, it is not possible to eliminate subliminal or subconscious change of the marking schedule by the course lecturers as a contributing factor to the observed improvement in pass rate. Further investigation of this factor is planned for the second cycle of the research.

Recommendations for the Second Action Cycle

There is strong evidence from student interviews (and empirical evidence from examination results and lecturer feedback) that the diagnostic test had a very desirable effect as both a “wake up” call and a motivating factor. Repetition of this test is viewed as highly desirable. It may also be desirable to combine the administration of the diagnostic test with a (pre-course) questionnaire probing student confidence in their high-school physics preparation, thus allowing a better gauge of the diversity of the incoming student cohort. Similarly, it would be desirable to expand the current course exit survey to include questions probing the extent to which the course has developed confidence in answering physics-based electrical engineering problems.

The student interviews (particularly of students of average or lower ability) were strongly supportive of the continued and expanded use of OASIS. Specifically it is recommended that OASIS questions be developed on areas not currently covered (e.g. transistors and operational amplifiers).

During the student interviews, some interviewees expressed gratitude that staff were taking the trouble to probe the issue of the high-school to year-one transition, and it is recommended that the monitoring be continued and expanded to include all year-one courses. In a related vein, a pre-semester (physics) catch-up course would also appear to be highly desirable as a way of bridging the gap for students with weak physics preparation.

Since (unconscious) modifications to examination marking schedules cannot be eliminated as a possible factor in the improved student performance, this facet will be probed further in the second action cycle.

Conclusions

All of the aims of the first action cycle have been achieved.

Analysis of the correlations between high-school physics results and the year-one course results indicates that the most significant determinant of examination success in ELECTENG 101 was whether students had studied the NCEA electrical module rather than the grade achieved for the module.

While student and teacher interviews highlighted that there are appreciable variations in content and depth of coverage between the various entrance qualifications (NCEA, CIE and IB), the feedback was that the course content, delivery and support mechanisms were adequately addressing this problem.

A diagnostic test was administered in the second lecture of the Electrical and Digital Systems course with the aim of identifying the level of preparedness the student cohort brought to the year-one course. This diagnostic test was valuable as a "wake-up call" and led to behavioural changes on behalf of students and to some modification of course content. Such tests should not be used as a predictor of success, but rather as a guide to teaching and assessment and to motivate students.

As is often the case with action research, the reflective practice and analysis which were part of the research process informed teaching, support and assessment practices even during the first cycle. Teaching staff made changes, perhaps both consciously and unconsciously, to content, supporting resources and assessment items. The success of these changes has been evidenced by higher pass rates for similar entering cohorts of students, and also by increased understanding through the duration of the course.

Acknowledgements

The authors acknowledge the assistance received from Student Administration at the University of Auckland to access the data used for NCEA and CIE analysis.

Bibliography

1. Cleland, A. (2007). A great time to be an engineer? *InRoads, August.* Pg 6. Accessed at http://www.ipenz.org.nz/ipenz/Media_Comm/2007/InRoads.pdf on 17 August, 2007.

2. French, B. F., Immekus, J.C. and Oakes, W. (2005). An examination of indicators of engineering students' success and persistence *Journal of Engineering Education* 94(4): pp. 419 - 425.

3. Besterfield-Sacre, M., Atman, C.J. and Shuman, L.J. (1997). Characteristics of freshman engineering students: Models for determining student attrition and success in engineering. *Journal of Engineering Education.* 86, pp.139-149.

4. Seymour, E. and Hewitt, N.M. (1997). *Talking about leaving: why undergraduates leave the sciences.* Boulder, CO, Westview Press.

5. Lam, P. C., Doverspike, D. and Mawasha, P.R. (1999). Predicting success in a minority engineering program. *Journal of Engineering Education, 88(3) pp 265-267.*

6. Thomas, Steve (2007) Fixing the NCEA: Ongoing problems, current reforms and proposed changes. Policy Paper. Education. Maxim Institute – retrieved from http://www.maxim.org.nz/files/pdf/policy_paper_ncea_reforms.pdf 10 January 2007

7. Riding, P., Fowell, S. & Levy, P. (1995) An action research approach to curriculum development. *Information Research, 1(1).* Accessed at http://InformationR.net/ir/1-1/paper2.html on 26 September 2006.

8. Steif, P.S. & Hansen, M.A., (2007). New practices for administering and analyzing the results of concept inventories. *Journal of Engineering Education, 96(3)*, pp 205 - 212

9. Smaill, C., Godfrey, E, and Rowe, G.B. (2007). The transition from final-year high-school Physics and Mathematics to first-year Electrical Engineering: A work in progress. Paper presented at the 18th Australasian Association of Engineering Education Annual Conference. Melbourne: University of Melbourne.

10. Shulruf, B., Hattie, J. and Tumen, S. (2007) *The Predictability of Enrolment and First Year University Results from Secondary School Performance*
Auckland: Starpath: Project for Tertiary Participation and Success, University of Auckland.

11. U.S. Dept of Education's National Center for Education Statistics' (NCES) survey, *"IPEDS Completions Survey – Degrees/Awards Conferred (NSF population of institutions),"* with survey data obtained from the National Science Foundation's WebCASPAR database. Accessed on 12 January 2007 from http://www.dedicatedengineers.org/news_pubs/Critical_Issues_Women_6-06.pdf

12. Godfrey, E. (2003). *The culture of Engineering education and its interaction with gender: A case study of a New Zealand university*. Unpublished PhD dissertation. Curtin University of Technology**,** Perth, p. 423. available at http://adt.curtin.edu.au/theses/available/adt-WCU20040105.130533/.

13. Smaill, C. (2005) The implementation and evaluation of OASIS, a web-based learning and assessment tool for large classes. *IEEE Transactions on Education, 48(4)*, pp 658-663.