AC 2009-538: INNOVATION AND INTEGRATION IN AN IN-HOUSE FIRST-YEAR ENGINEERING PROGRAM: A FAST TRACK TO ENGINEERING ENCULTURATION

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Innovation and Integration in an In-house First-Year Engineering Program: A fast track to Engineering Enculturation

Abstract

The first-year of the four-year Bachelor of Engineering (Honours) program at the University of Auckland has been taught entirely in-house by the School of Engineering since 1996, when university-wide structural changes enabled the fulfillment of "a strong desire to move students straight into the engineering way of thinking". The changes made were seen as matching well with international calls for engineering education curriculum reform. This in-house program is very rare in an international landscape where the majority of first-year engineering courses, are taught as service courses by faculty from mathematics and science departments with one or two design or hands-on introduction-to-engineering courses providing a taste of "real" engineering. This paper charts the evolution of that program, its strengths, challenges, weaknesses and ongoing evaluations with particular reference to innovations in delivery and assessment in the context of an integrated curriculum. The common program, taught entirely in-house, provides the opportunity for the early development of a sense of belonging and identity as an engineer. Data presented in the form of student feedback, assessment results and evaluations suggest that this program may well provide examples of best practice.

Introduction

In the mid 1990s a series of international reviews of engineering education[1,2,3], called for engineering graduates to be:

> "more outward looking, more attuned to the real concerns of communities. Courses should promote environmental, economic and global awareness, problem-solving ability, engagement with information technology… communication, management and teamwork skills, but on a sound base of mathematics and engineering technology" (IEAust, 1996)

Simultaneously, recruitment of a larger and more diverse pool of applicants, and retention through to graduation, were spotlighted as major concerns in response to demands for more engineering graduates from industry and the profession. Over the last ten years, the dialogue surrounding the need for change in the education of engineers has become even stronger[4,5] and engineering degree programs have responded with program and curricular restructuring, pedagogical innovation, the increased use of problem based learning, and a gradual shift in the discourse from "teaching" to "learning". Issues of student engagement, transition and attrition during the first-year of higher education have become a major focus - as evidenced by an expanding literature, conference sessions and even the creation of a separate journal[6]. Within engineering, recruitment and retention issues have been identified as a major concern and area of study [4,7,8]. A plethora of recruitment initiatives, attempting to enlarge the potential pool of applicants, can be found in the literature and provide exemplars of best practice. For retention through to graduation, the need to build more, and stronger, connections between first-year curricula dominated by mathematics and science courses and potential engineering career paths was recognized as highly necessary if attrition from first-year engineering studies was to be reduced[9]. The approaches to first-year engineering programs reported on by Baillie[10] in 1998, collated from a survey of over 100 institutions in 12 countries, could be viewed as the "combined wisdom about best practice" at that time. She identified six major categories in approaches to first-year engineering programs. These were: creating a short introductory course, additional help with one aspect of the course, developing a new or overhauled subject, introducing an entire curriculum change,

mentoring/tutoring by staff and peer tutoring. At that time, Baillie identified that the most common way institutions were addressing first-year issues was by the introduction or change of an existing subject with an attempt to link the various parts of the course in the context of 'how to think like an engineer'.

A large number of institutions in the United States, by way of NSF-sponsored coalitions during the 1990s, have attempted to completely revamp their curricula, using integrated approaches to teach the basic sciences in an engineering context whilst promoting professional skills development such as - report writing, teamwork and oral presentations[11,12]. Ten years after Baillie's survey, however, a review of the literature and program structures reveals that many engineering programs are finding transformational change challenging.

The difficulties in transforming first-year programs were articulated by Katehi et al[13] who spoke about the need to find a balance between a number of opposing forces. They recognized that a minimum of fundamental knowledge in science and mathematics was required to prepare students for more specific engineering coursework, but exposure to the nature of engineering and its opportunities was also needed to enable students to identify and confirm an appropriate career path. Also competing with these forces were the calls to educate students in areas of communication, ethics and professionalism, design, working in teams, leadership, entrepreneurship, and global understanding (to name a few), all vying for curriculum time.

Froyd and Ohland[9] provide comprehensive evidence from research which suggests that integrated curricular programs encourage students to affiliate and develop learning communities, which lead to improved persistence and retention. In the United States, it appears however, that integrated curricular programs are rare. The majority of first-year (freshman) engineering programs, including the program spoken of by Katehi et al.[13] are currently structured with mathematics and science classes taught as service courses from outside engineering, with one or two courses in the first-year program focusing on Design and/or Introduction to Engineering. These introductory engineering courses, which aim to motivate and stimulate first-year students to start thinking like engineers, are often well-resourced, using innovative technological and pedagogical methods.

The situation is somewhat different in Australia and New Zealand. A recent survey[14], conducted over 35 institutions, revealed that eleven institutions offered, or will offer in the next year, a first-year program, of which at least 75% of the courses were taught by academics from within Engineering. All of the first-year programs surveyed include an introduction to the engineering profession and engineering life-cycle and/or an Engineering Design course, with some excellent examples of active and project based learning based on real-life engineering problems.

The longest-lived of these integrated, common first-year programs is that offered by the University of Auckland (hereafter named U of A), taught entirely in-house since 1996. This paper charts the evolution of that program from its first incarnations in 1996 through consequent structural and curriculum amendments to the present. The strengths, challenges, weaknesses and ongoing evaluations of that program are presented, with particular reference to innovations in delivery and assessment.

At this time when research is showing that the process of "becoming an engineer"[15] and the construction by students of their engineering identity[16,17] are important issues for retention, the opportunity for the early development of the sense of belonging and affiliation, provided

by a common program taught entirely in-house suggests that this paper may provide exemplars of best practice for other programs.

History and Background of the U of A First-year Program

The U of A is a high-ranking research-led university with an undergraduate engineering student body of approximately 2500, the largest in New Zealand. The first-year intake is currently limited to a total of 620 students. The School of Engineering, which recently celebrated its centenary, offers degrees in nine engineering specializations.

All Bachelor of Engineering students follow a set of common Part 1 courses which provide a solid foundation of engineering-science fundamentals across all disciplines. Students are selected at first-year entry for a limited number of places, and almost all the incoming students have a high level of competence in Mathematics with Calculus and Physics at final year high-school level. Applicants who are not well prepared in core areas are given guidance to pre-entry preparation and alternative admission pathways.

Prior to 1990, a first-year of science courses, known as an Intermediate year, was completed before acceptance to engineering. In 1991, recognizing that almost all those who were ultimately accepted in to engineering had strong school qualifications, students were selected directly to a common first-year engineering program although they nominated a specific engineering specialization for their further study. From 1991 to 1995, this common first-year program was composed of Mathematics and Science courses taught by the Science Faculty, with only two, a combined Mechanics and Design course, and the Engineering Computing course, taught by Engineering staff.

As the result of a university wide project to simplify and unify degree structures, commencing in 1996, the opportunity was taken to completely restructure the engineering degree. In particular, faculty staff believed that:

> "Our students are frequently unmotivated and bored by their course"
>
> "Our students have very heavy workloads"
>
> "The first-year of the BE course is not focused on engineering and our students do not feel that they are engineers". Field notes - Faculty meeting, July 1994 from Godfrey[20]

Cognizant of the discussions and international reviews of engineering education that were taking place at that time, one goal of the new course was:

> "to bring the students straight into an engineering way of thinking"
>
> Interview with Dean of Engineering, July 1997 from Godfrey[20]

The new structure embraced the ideas of: reducing the workload to make time for more independent learning and reflection, increasing the use of project based learning in all subjects, including at least one Design course in each year of each specialization and including explicit common core courses to prepare graduates for professional life including social and environmental responsibilities.

> "The IEAust Review came out soon after we started, and I felt we could have written it, our new degree matched what they wanted done – so our thinking was really up there with current engineering educational thinking." Quote from Faculty meeting, Nov 1998 from Godfrey[20]

An increased level of retention was not a motivating driver for the restructuring. In the years prior to 1996 attrition from first-year had been as low as 5%, and was not viewed as a concern.

The Common first-year program implemented in 1996 had the following goals:

- To develop
  - fundamental engineering problem solving skills
  - a logical and lateral approach to problem solving and design
  - the ability to use computers as design and analysis tools
  - the ability to design and construct useful experiments
  - the ability to use mathematics to describe and analyze a physical problem (including the ability to sketch, approximate and estimate)
  - the ability to communicate engineering concepts to others by written and oral means
  - the ability to work effectively in groups
- To reinforce the problem solving skills with design projects that attack 'real' industrial problems
- To introduce all students to the various engineering disciplines and their interaction with society

The course structure of the common Part I program implemented in 1996 is listed in Table 1, with course prescriptions contained in Appendix A.

Semester 1		Semester 2	
Mathematical Modelling 1	2pt	Materials Science	2pt
Engineering Mechanics	2pt	Electrical Engineering Systems	2pt
Engineering Design	2pt	Engineering Computing	1pt
Environmental Principles	1pt	Approved Elective	2pt

Table 1 Course structure of Part I program implemented in 1996.

The major hurdle to implementing this program, for which the School of Engineering would have full control of content, and course delivery, was the loss of revenue (based on enrolled student numbers) by departments which had previously delivered mathematics and science content as service courses. After much debate, compromises were reached, with content control in the hands of Engineering but some (in one or two subjects) teaching and laboratories provided by Science faculty. By 2005, however, all courses were taught completely in-house by staff from within Engineering.

Between 1996 and 2005, the only major change to the structure of the first-year was the shifting of the Environmental Principles course to the second year, and the introduction in 2001 of a first-year paper entitled Professional Development 1. This change was made partly in response to the desire to introduce students as early as possible to the role of professional engineers and professional bodies, and the need for professional skills such as writing and documentation, but also partly in response to student resistance and lack of maturity in dealing with the issues and content of the Environmental Principles course.

In 2006, the move by the university as a whole from a 14-point (seven course) year to a 120-point (eight course) year provided an opportunity to address several pedagogical issues. The

driving force for this move, as so often happens, was not the optimization of teaching and learning but a government requirement for all universities in New Zealand to adopt a common measure of academic credit based on a full time year of study. It did, however, enable and motivate a comprehensive review of all courses offered in Part 1. The restructured Part I, by unanimous Faculty decision, remains a common program of eight x 15-point courses for all first-year students, one of which was required by University mandate to be a General Education course. Each of the new 15 point courses would involve 10 hours of student time per week with four hours formal contact time via lectures and tutorials, laboratory time where relevant, while the remaining time was self learning time for students to complete problem exercises, assignments and independent study.

Four courses remained essentially unchanged, albeit with content reduction. These were the two-point courses Mathematical Modelling, Engineering Mechanics, Materials Science and Electrical and Digital Systems. The Design course, previously taught as two one-point courses over a full year became one 15-point course taught in a single semester. The restructuring also enabled the Engineering Computing course to move from a 1-point course to a full 15 point course called Engineering Computation and Software Development. Moving from seven to eight courses also enabled the introduction of the new course Biology and Chemistry for Engineers to be added. Course prescriptions for the first-year courses implemented in 2006, listed in Table 2, are available in APPENDIX B

A no-credit compulsory English Language Competency course was also introduced from 2006 as a Part I requirement. For course completion, students are required to complete a diagnostic assessment to a satisfactory level. If deemed appropriate they then complete 30 hours of remedial work with the university English Language Center and Student Learning Unit with subsequent re-assessment for course completion.

Semester 1	Semester 2
Mathematical Modelling 1	Materials Science
Engineering Mechanics	Electrical and Digital Systems
Biology and Chemistry for Engineers	Introduction to Engineering Computation and Software Development
Introduction to Engineering Design	General Education course (elective)

Table 2 Bachelor of Engineering Part I program implemented 2006

The Common First-year Core Courses

The first-year programme is seen as an important introduction to the degree and to the engineering specialisations, with each engineering department conscious of displaying their specialisation to its best advantage. Consequently the first-year courses are viewed as “show cases” for each engineering specialisation, and the courses are taught predominantly by experienced, top-quality academic staff, often quite senior (to the surprise of many first-year students). Recognising that many of the incoming students are school leavers, several academic staff with strong high school teaching experience have been hired explicitly to work alongside tenured academics to aid the transition from school-based knowledge and learning styles to those of the university.

Mathematical Modelling 1

Mathematical modelling forms one of the core themes running through the University of Auckland's undergraduate engineering degree. When the current BE was designed in 1996, a conscious effort was made to emphasize the development of skills in model building, in contrast to traditional undergraduate courses in applied mathematics which place primary emphasis on mathematical skills required to solve mathematical problems. All engineering students take courses in mathematical modeling for the first three years of the degree (Part I, II and III). These courses are tailored somewhat to the needs of each engineering discipline. The focus on modeling takes emphasis off the formal development of mathematics for its own sake and places it more of the development of a mathematical toolbox with which to solve particular classes or problems.

The Mathematical Modelling 1 course (taken by all first-year students) draws on examples from a range of engineering disciplines. For example the module on differential equations includes examples which develop mathematical models of the current in an electric circuit, and the displacement occurring in a shock absorber. This multi-disciplinary view point is also part of the assessment process. In one assignment students must construct a free-body diagram (a concept from the first-year Mechanics course) of the forces acting on a decelerating train. The students then use mechanics concepts to develop a mathematical model governing the forces on the train. Students then apply mathematical techniques (in this case partial fractions and integration) to solve that model. Lecturing staff also often introduce examples of the use of mathematical-modelling techniques from their research or consulting activities into lecture room discussions. For example staff have demonstrated computational models of the heart while discussing matrix algebra, and have discussed work on the interpretation of pressure-versus-time data from oil wells while discussing partial derivatives.

Students generally respond well to this philosophy as these comments from the 2006 Fast feedback survey illustrate:

"I found Mathematical Modelling 1 really exciting, purely because it challenged us to really use our minds in solving maths problems from Calculus to Statistics. It improved my understanding of different maths concepts used in solving real life problems, and what made it even more exciting was knowing that what we are learning now is actually employed by engineers in real life situations."

"What struck me, is that maths is a tool. It is not the maths that is important, but the stuff you do with it, applying it to a problem"

Engineering Mechanics

The Engineering Mechanics course is a traditional Statics and Dynamics course offering many opportunities for contextual, case study connections. It is taught by Civil and Mechanical Engineering academic staff with a mixture of tenured academics and graduate assistants assisting in smaller group tutorials. Peer assessment aimed at assisting students to gain deeper learning in this course is described in a later section.

Materials Science

Materials Science has been seen as a challenging course with much of the content and terminology new to students but it consistently scores highly in student course evaluations across the Part I program. It is taught by enthusiastic, highly-motivated staff, winners of numerous Teaching Excellence Awards both within the institution and nationally. The theoretical content is extended with many practical demonstrations, connections to engineering applications and case studies. Teaching resources have included an innovative

computer-based resource. Two modules that use this resource and are described in the paper by James and Ramsay [18], are "Microstructure and Mechanical Properties" and "Phase Diagrams". Each module comprises hypertext, schematics, animations (both two and three dimensional) and revision questions. In addition the "Microstructure and Mechanical Properties" module provides three virtual laboratories, with a high degree of interactivity, and a video on casting to provide context to the module. Student feedback indicated a high level of satisfaction with the modules and praised the video and structure of the revision questions in particular.

Electrical and Digital Systems

The delivery of this course is made easier by the assumption that all students have studied physics at final-year high school level, although it has become clear that the topic of electricity and magnetism may not have been studied in depth by all students[19]. Whilst providing the basic principles and concepts of electricity, electronics and electromagnetism the course aims to connect this theory to engineering applications in real-world examples. The topic of Power Systems, as an example, is introduced with reference to the generation, transmission, distribution and consumption of electrical power in New Zealand. The course serves as background for students who will enter the full range of engineering specializations, but also ensures sufficient fundamental knowledge for those who will major in Electrical and Computer Engineering.

Introduction to Engineering Design

Engineering Design accounts for close to 15% of most four-year engineering degree programs at the U of A, with Design courses in each year of the program. This introductory course aims to present an engaging environment where students can be exposed to a range of design activities, each of which has the flavor of a real engineering problem, whilst challenging and engaging a student cohort which is highly able academically but has a wide range of practical experience. Within this overall concept approximately one third of the course is devoted to the acquisition of drawing and sketching skills including the use of CAD software, one third to the solution of conceptual or real design problems and the balance to design, build and test projects. An increase in cohort size from 270 in 1996 to the current 600, has challenged both infrastructure and human resources, necessitating compromises in delivery and assessment techniques from time to time. Although teaching staff are drawn from the Civil and Mechanical Engineering departments, a priority is to emphasize that the Design process is an intrinsic part of engineering thinking and doing, in all specializations. Consequently, when designing projects, staff are mindful that this introductory course must engage students who intend to major in the full range of engineering specializations.

Most of the course has been taught using a problem-based, small-group approach, with the design-and-build projects being the highlight of the course for most students (as demonstrated by the number of short video clips posted to youtube.com). The design-build-test projects are particularly useful in reinforcing the design process since the various steps of: initial brainstorming, analysis of ideas, optimization of design, mathematical analysis, repeated comparison with specifications, production of a report, drawings, and construction and testing - are easily identified. Although some details of the success of skill development in teamwork are discussed in Godfrey's research[20], several initiatives in content and delivery, as well as trials of self- and peer-assessment merit further documentation and research.

Introduction to Engineering Computation and Software Development

Engineering Computing started originally in 1991 with a focus on application software. The first restructuring in 1996 saw an introduction to MATLAB programming added to the curriculum. During this time, students who aimed to continue in either Computer Systems or Software Engineering were required to complete a Computer Science programming course as an elective in their first-year. With the restructuring in 2006 this elective was no longer available, and surveys of first-year students indicated that the vast majority were already entering University with a familiarity of the basic fundamentals of applications software. It was also recognized that all engineering graduates in the future would require knowledge, albeit at a basic level, of the potential capability of software development in the solution of engineering problems. As a consequence, the course currently offered now carries the same credit as other Part I courses and provides both essential programming skills for mathematical modelling using MATLAB, and an introduction to software development using the C programming language. Staff delivering the course are from the departments of Engineering Science and Software Engineering. Innovative assessment and feedback techniques have been implemented in this course, and are discussed in a later section.

Engineering Biology and Chemistry

Details of this course are described under Curriculum Innovation later in the paper.

Evaluation

Evaluation of the effectiveness, relative to its goals, of changes to the first-year program has not been undertaken as a specific research project. Since 1996 however the program as a whole, individual courses, and innovations have all been subject to a range of reviews and audit procedures. These have included:

- Formal audit during processes of external accreditation by IPENZ and internal review by the University which took place in 1995, 2000 and 2005
- Evaluation of new courses and programs at the request of the School of Engineering by the university Centre for Academic Development as outlined below
- Fast Feedback surveys – internal School of Engineering surveys are conducted on every course every semester to quickly highlight strengths and weaknesses in course delivery – with each course receiving a summative score based on a Likert scale.
- Annual course audits by each department
- Part I retrospectives – a day-long annual review
- Formal research by individual staff members (Godfrey[20]; Smaill[21]; Smaill, Rowe and Godfrey[19]; Denny et al[22,23;] Hamer et al.[24,25]; and James[18]) has used statistical data, surveys and qualitative methodologies to investigate aspects of the first-year program since 1996.

It should be noted that evaluation of change to ongoing programs such as this has been seen as problematic. As Baillie[10] noted, it is difficult to extract evidence about the effectiveness of a course or program by the results of an evaluation other than by students' grades or student evaluations. Using quantitative data such as student grades or student evaluation scores to prove that change has been effective may provide trend information but is fraught with sources of error, including variation in content, teaching style, teachers and the student

cohort. There are difficulties with both quantitative and qualitative approaches. Interview and discussion-group material, for example, is subject to bias, as it is almost impossible to be objective about something we develop and own. Baillie suggested that a triangulation of approaches is needed as evidence of change achieving desired aims. For this program one of the most significant indicators must be high retention, demonstrating high student engagement and identification with the program. Other indicators could be public and professional recognition of the course, and imitation of aspects of the model by other universities in New Zealand.

The majority of evaluation has been undertaken by the University Center for Academic Development, which provides reports using qualitative and quantitative instruments for evaluating new and ongoing courses and programs.

The 2000 Accreditation documentation reported that, the Centre for Academic (formerly Professional) Development undertook a student evaluation at the end of each semester of the first-year of the new BE degree in 1996 using surveys and focus groups. In general, students rated the first-year between OK and GOOD. The highlight for many students was the Design course, and qualitative responses gave high praise for the problem-based tutorials. Nearly 70% of all students, particularly female students, agreed that the program had helped their understanding of the profession of engineering. Students were critical of heavy workloads and poor timetabling, but very positive about the integrated program and the inclusion of projects and practical work. It was clear that where lecturers put effort into making lectures relevant, illustrated with practical examples, students appreciated these efforts.
An internal audit of the first-year courses was also held at the end of 1996, using student and staff feedback to assess what was done, what appeared to have been successful, and what areas could be improved. Alterations to content particularly to include more relevant, in-context examples, the timing and number of projects and assignment, and the timetable were made for 1997. Further surveys were conducted in 1997 to evaluate Part I and Part II courses and results were discussed with course co-ordinators.

An internal formal Review of the Part I program was conducted in 1999. The majority of staff teaching Part I were interviewed and student focus-group contributions were included. The Reviewer was extremely impressed with the dedication, enthusiasm and efforts being made by the teaching staff at this level. Some specific concerns were noted:

- Vulnerability – course organizers working under extreme constraints of time, space and personnel. Efficiency was very vulnerable to breakdown of any part of the system.
- The lack of small-group discussion spaces, and model-building facilities impact significantly on the benefits to be gained by project based learning."

The Review recommended closer co-ordination of all staff involved in Part I and regular meetings were held in 2000. Another recommendation was that the Environmental Principles course might be more appropriately taught in a later year when students had a more mature overview of engineering, and life in general. It was a consequence of this review that the Professional Development 1 course was offered in 2001, with the Environmental Principles course reincarnating as an Engineering Sustainability course for all specializations at Part II level.

Since 2004 a comprehensive day-long review of Part I, known as the Part I Retrospective is conducted at the end of each academic year. This review is led by the Chair of the Teaching and Learning Quality Committee, involves all staff who have taught into the program, and is

attended by the Dean or Deputy Dean. Issues with each paper are addressed, but also a broad view of the overall preparation for subsequent degree specializations is considered.

Fast-feedback surveys are conducted in every course in every semester.These are considered a "quick and dirty" monitoring system, but do allow a fast response where difficulties or weaknesses are identified. The results from these surveys are not used for staff promotion purposes, and evaluative instruments are tailored by the Centre for Academic Development where a staff member wishes to seek feedback of a personal nature or to evaluate a specific initiative in teaching or assessment. The School of Engineering also complies with the University-wide three-year rolling plan of course evaluation. There is a perception that courses are comprehensively evaluated, and in fact there is some talk of "survey overload".

Challenges

Over the period of thirteen years that this program has run, challenges have abounded, some a feature of teaching and administering large classes, others more specific to implementing an in-house program which has gone from approximately 270 students in 1996 to a capped level of 620 in 2008. These have included:

- funding – as referred to earlier, there are "political" implications within a large institution when redirecting funding based on student course numbers and teaching departments
- resource and timetabling constraints - both human resources and infrastructure over the years have been stretched, although recent building works have alleviated these
- student resistance to some courses, viewing them as irrelevant to their final choice of major
- faculty overload - particularly where the focus is on problem based learning and when numerical growth often precedes resource allocation
- finding staff with appropriate expertise, interest and ability to teach at first-year level
- large-class assessment – particularly assessment moderation between tutors, and issues of plagiarism,
- curriculum decisions – particularly finding a balance between appropriate content for all students but also adequate preparation for further specialization.
- diversity of backgrounds - changing qualification systems in New Zealand have led to increasing diversity in the academic background of the incoming cohort [26]. (Diagnostic testing using modified course-concept inventories has been used from 2007 to identify students potentially "at risk").

It is recognized that there is no silver bullet or unique solution to these challenges. Experience at the U of A has demonstrated that sometimes idealism is constrained by unforeseen events, requiring a high level of flexibility, an acceptance of compromise for a 'best' solution, all assisted by a strong sense of humor. Despite these challenges, the first-year program continues long term, with ever-increasing commitment and innovation.

Curriculum Innovation

The most notable and unique of the curriculum innovations, other than the entirely in-house nature of the course, has been the introduction of the Engineering Biology and Chemistry course. Chemistry and particularly Biology are playing an increasingly important role in

many engineering fields. With the typical engineering program already overcrowded, only a few institutions have managed to incorporate them into first-year programs[27,28] and then not as a core component for all first-year students.

Engineering Biology and Chemistry

The combined Biology and Chemistry course arose at the time of the 2006 restructuring, to satisfy the need for basic chemistry and biology knowledge, especially for those students planning to specialize in Chemical and Materials, and Biomedical Engineering. Incorporating the course in the common first-year program was supported broadly by all Departments who recognized the need for the students to be exposed to the interdisciplinary knowledge necessary in order to address present and future challenges such as Water Supply, Energy and Healthcare. The course is based around two main themes, Energy & Fuels/Bioenergetics and Water & Ecology. Over the three years of running the course the content has evolved to look at fewer topics within these themes, but at greater depth.

The course covers basic concepts in chemistry (mainly physical chemistry -thermodynamics, work, thermo-chemistry, distillation, properties of water, diffusion, osmotic pressure) and biology (cell structure, respiration, enzymes, biomechanics, ecology), in the context of engineering applications. It was crucial from the beginning that the course did not become a disparate collection of material, but used a systems approach to demonstrate the application of chemistry and biology to address engineering issues – reflecting the importance of cross-disciplinary knowledge. A systems approach was adopted with themes chosen that not only were topical but also where engineering, biology and chemistry overlapped, or could be readily linked –Energy & Fuels, Bioenergetics, BioMechanics, Ecology & Water. The first section of the course, within the Energy & Fuels theme, for example, examines how chemical energy is converted to mechanical movement for man-made systems (a car engine). Then Bioenergetics looks at how biological systems utilize chemical energy. Comparisons are drawn between the efficiency of biological and man-made processes, the rate of combustion reactions versus respiration, and the temperature at which the processes take place. BioMechanics follows on by examining how biological systems convert chemical energy into mechanical movement (heart and lungs). Each theme begins with a big-picture, overview lecture to put the topic in context, to demonstrate the engineering challenges and their social implications.

Possibly the biggest challenge is the diversity of chemistry backgrounds. After surveying students each year we have settled on the assumption that all students would have studied basic General Science for three years (compulsory in New Zealand) at high school, but very few would have continued with advanced Biology. Because much of the chemistry related content is not covered in high-school courses, the engineering focus holds the attention of both the stronger and weaker chemistry students. Students have responded well to the course, after a small level of resistance in the first-year of delivery, and ratings on both the Faculty fast-feedback surveys and course-specific feedback surveys have seen a marked improvement in student satisfaction. Results from the course-specific survey on a 10 point scale were: 5.92 in 2006, 7.14 in 2007 and 7.57 in 2008, affirming changes which had been made in the number and depths of topics covered and the student perceptions of relevance. These comments from the 2007 survey are illustrative:

"Really cool course, well organised. Especially enjoyed finding out about how biofuels worked, about energy and car engines, also the concept of desalination, and current events in ecology."

"Liked the topicality of most parts of the course and the constant linking of it to current engineering problems."

The 2006 restructuring had removed the First-year Professional Development course and the development of professional "soft" skills of writing, communication and team work were distributed amongst the other first-year courses. Consequently, a web-based research assignment was developed with the aid of a teaching grant. This assignment, based around the theme of Biofuels incorporated library skills (tested via an online quiz), and provided website linkages to interviews, theory and numerical data, All research and steps were online although the final deliverable was a hard-copy report.

Assessment - Formative and Summative – Innovation

Assessment in large classes is always challenging – in terms of workload for the assessing team, and also in terms of ensuring that students receive prompt formative feedback which will contribute to their deeper learning. Several of the initiatives described below require students to take responsibility for their own learning and as the evaluations demonstrate, have contributed to high student engagement.

Peer Assessment in Engineering Mechanics,

The Engineering Mechanics course focuses on problem solving in the Part I curriculum, specifically interpreting engineering situations and analyzing the forces and motion involved. The standard of communication in the worked solutions shown by students in tutorial problems, tests, and the final exam was often found to be inadequate. When tutorials (small group problem solving sessions) were cut from two hours to one hour in 2005 due to resource and timetable constraints, the lack of opportunity to provide formative feedback was exacerbated. The course co-ordinator, whilst completing a Graduate Certificate in Tertiary teaching was inspired by the work of Gibbs[29] to explore and implement peer assessment as a means of addressing this issue.

In this Peer Assessment implementation, the students prepared full solutions by hand to two exam-level problems for each exercise. In the tutorials, students' work is distributed to the other students along with a grading scheme and a model answer. The exposure to other students' working allows them to appreciate different approaches to the solution and both good and bad working. Transparency in the grading scheme is deliberate; it is emphasized that tests and exams are graded in the same way. Students' graded work is returned within approximately twenty minutes. Because the students are not experienced graders, the feedback they give is acknowledged to be of little significance. More is gained pedagogically through preparation of well set-out solutions and exposure to the grading process.

Peer assessment (PA) exercises were introduced to the course in 2005, initially as a trial in one tutorial session. From 2006, the exercise was expanded to four (of 11) tutorial sessions throughout the semester in all tutorial streams. Spreading the workload over the course encouraged time-on-task. A 1% course credit was added in 2007 for participation in each exercise but no grade given for performance.

Students were surveyed at the end of the course about their experience with Peer Assessment. In response to the item 'Overall, PA is a valuable form of feedback,' students gave mean scores of 7.1/10, 6.8/10, and 5.6/10 in 2008, 2007, and 2006 respectively. The improvement in student perception of PA overall is encouraging. Most students felt that it was their preparation of solutions for PA that was most valuable. The small 4% course credit given to participation in the exercises has proven to be a sufficient incentive and over the past two years, 83% of the class has participated in all four exercises. Those students participating in

fewer exercises, scored a mean final grade lower by 12% in comparison to the entire class, which suggests a correlation between participation and performance.

Peer Assessment in the Introduction to Engineering Computation and Software Development Course Using Peerwise and Aropä

When the ENGGEN 131 course was restructured in 2006 to become a full 15-point course, staff took the opportunity to reflect on the assessment and feedback structures. The practicality of providing timely feedback on a regular basis to more than 500 students was of some concern. Several innovative approaches incorporating aspects of a contributing student pedagogy[24] were introduced, both for encouraging students to engage with the course material, and for providing fast and regular feedback.

- ***PeerWise***

PeerWise [22] is a web-based learning tool that provides a framework allowing students to create multiple-choice questions (MCQs) and contribute them to a shared repository, where they can be answered, rated and discussed by other students. In this course, students were each required to submit two questions to PeerWise on any topic they chose. In addition to writing the question stem and providing a set of alternatives, students were also required to provide a detailed explanation of the correct answer. All students were given access to the shared repository, and were able to answer as many questions as they liked, each time getting immediate feedback on their submitted answers. They were also given the opportunity to rate and discuss the questions.

This activity provided a number of benefits to students. Firstly, it presented unique opportunities for self-assessment. In addition to seeing whether their answer was correct, each student was also shown a histogram of the alternatives selected by other students, allowing them to compare their answers with the most popular answers of the class.
The process of creating questions encouraged students to reflect on the learning outcomes of the course, and to express their understanding of a topic in their own words. It was also an effective way to create a large repository of revision questions in a short time. In 2008, over the period of the semester, 550 students developed 2500 questions, and these were answered, rated and discussed 53000 times. The development of such a resource was only possible by leveraging the intellectual capacity of the entire class.

Students responded positively to the use of PeerWise in this course[23], and indicated in surveys that they enjoyed the process of answering their peers' questions, and felt a sense of belonging to a community:

"It is good to interact with the community, and see what level the rest of the class is at when it comes to their knowledge. Also the feedback on my questions is great!"

"Peerwise was awesome! I managed to answer over 100 questions which helped me improve with the basic knowledge!! I actually enjoy answering questions and writing comments and rating questions except just wish there was a fast way of doing all of that!"

"Wow, what can I say, Peerwise is one of the best learning tools I have used. The neat thing is encouraging the Peerwise community, in a similar fashion to social networking sites, by allowing feedback to be provided; and utilising a leaderboard. It is the sort of thing that gets people addicted to Peerwise."

Students also used the repository heavily for exam revision purposes, even once the assessment deadline had passed, providing evidence that students found value in the contributions of their peers.

- ***Aropä***

Students in this course were also required to peer-review one another's work. This activity was supported electronically by the peer-review system Aropä[25]. There were two large programming projects during the semester, collectively contributing 30% towards the students' final grade. Students uploaded their completed projects to Aropä, which was then used to manage the randomized distribution of a small number of submissions to all students in the class. Students then reviewed the submissions of their peers and entered their reviews online via a web form. These reviews were available for immediate viewing, giving students formative feedback often within hours of having submitted their project. For summative purposes, the projects were marked by employed markers, however these results were only available to students two weeks after the project submissions.

Having students review a selection of projects from their peers offered a number of advantages. They gained insight into the marking process and reflected on the way that their own work would be assessed. This led to a dramatic reduction in the number of re-marking queries that would typically be seen in a course of this size. Students were also exposed to a variety of ways of solving the project which they had just been working on, allowing them to contrast approaches and discover new problem solving techniques.

Another advantage of the peer-review activity was that good student reviewers could be identified by comparing their reviews with those of the employed markers, and by looking at the depth and quality of the feedback they provided. This allowed the staff to identify students who would be effective markers themselves. Markers for the course in 2008 were hired exclusively from students who had achieved a top grade in the course in 2006 or 2007 and who had a proven track record of quality reviewing.

- ***Class Wiki and forum***

In addition to PeerWise and Aropa, students used both a Wiki and an online forum to communicate and assist each other. Engagement with these community building tools was intended to help transform students from being passive receptors of information to becoming active members of a community engaged in the process of constructing knowledge.

The Wiki was used to encourage creativity, experimentation and written communication skills. Students were given the task of developing any kind of program they wanted, and were required to write a report on the process. The highly open-ended nature of this task gave motivated students an opportunity to be creative and extend themselves, and also resulted in a great variety of programs in both concept and quality. Each student then uploaded their report, and any associated materials such as source code or screenshots, to the class Wiki which was powered by MediaWiki software. In this way, a gallery of varied and unique programs was developed and available for students to browse. Unlike the Aropä peer-reviewing activity in which students were exposed to several example solutions of the same problem, this activity exposed students to many different solutions to many different problems. Staff selected particularly interesting examples from the gallery to showcase in class, providing recognition for the authors and inspiration for others.

Students in this course also had access to a class forum which used the popular open-source phpBB package. Students used the forum to post questions or describe problems they encountered, which could then be answered by other students or staff. While staff did regularly monitor the forum, students almost exclusively answered each other's questions, particularly as project due dates approached when forum activity increased significantly.

Online Assessment in Electrical and Digital Systems Using OASIS Software

As first-year class sizes increased from under 300 in the late 1990s to over 600 in 2007, much of the increased staff workload was perceived to lie in the area of assessment, both formative and summative. To assist in reducing some of this marking load on staff, without reducing the potential for student learning, staff from the Electrical and Computer Engineering Department developed OASIS (Online assessment System with Integrated Study)[30], a Web-based software tool that delivers individualized practice and assessment tasks, marks student responses, supplies prompt feedback, and logs student activity. OASIS was first used as a tool for skills practice with the large year-one class ELECTENG 101 in 2002. Despite receiving no grade credit for this practice, the average year-one student submitted answers to 100 OASIS questions. The OASIS questions covered only 40% of the course and the students also had tutorial and textbook questions to work though. Activity logs enabled the instructors to identify problem questions and associated learning issues were addressed in lectures or tutorials in a timely manner. Student feedback about OASIS was very positive and student performance improved dramatically in the final examination in the 40% of the course covered by OASIS questions. From 2004 onwards online tests using OASIS have been used in the year-one course and this has motivated even greater student practice activity with OASIS. An action-research project[21] that ran from 2002 to 2006 used evidence from a variety of methods, both quantitative and qualitative, to verify the benefits to student learning of online assessment using OASIS. This evidence included the extensive body of data collected by the software itself, course surveys, written responses from both present and past students, and recorded interviews with both instructors and students. The OASIS team were Highly Commended for the 2005 Australasian Association for Engineering Education Excellence Award for Curriculum Innovation. Since 2002, online assessment using OASIS has been introduced to more than a dozen courses in electrical engineering and physics, as a way of enhancing student learning whilst managing staff workloads. These two quotes from the study described in Smaill's paper[21] illustrate student reaction to OASIS. :

> I phoned a few friends to tell them that I was coming to talk about it and they said, "Yeah, it's an awesome exam resource. It was really good". I actually learnt how to do the problems. Like, there's different levels. You can know how to do it and you can understand why you're doing it, and then you can just do it automatically, if you know what I mean? And it took it from that level of knowing how to do it to understanding why you do the things that you do [student interview].

> The only thing I thought a bit flawed about OASIS was that it was easy for friends to get together and help each other out. I am guilty of this, but I also found this group-work was ideal for learning. So ultimately, I found OASIS was a real help for my learning [student email].

Enculturation - Sense of Belonging and Identity as an Engineer.

Engineering education has been described as "enculturation into a well-established system of practices, meanings and beliefs" by Tonso[31]. A program in which all courses are taught by engineering staff, focusing the fundamentals of engineering-science on engineering

applications provides a unique opportunity to start the process of enculturation and development of a sense of identity as an engineer. Although the majority of lecturing is done in large classes, small-group tutorials, and group projects, combined with daily close contact provide opportunities for study oriented friendships. From the first day at orientation, the students had an almost daily reinforcement via application-oriented lectures and assignments of their shared identity as engineering students. Godfrey's qualitative study[32] has commented in more detail on the process and effectiveness of this enculturation. The following student comments, taken from that study demonstrate that engineering students, even in their first-year, had gained some appreciation and ability to recognize an "engineering way of thinking" and "way of doing" and what it meant to be an engineer:

> Thinking like an engineer, kind of being taught it I suppose. The whole course is directed at making you think differently, that is how I feel it. (John, 1st year student)

> I think that thinking as an engineer is thinking of the theoretical best solutions to problems and then the best practical way of doing it (Joshua, 1st year student)

These comments illustrated that academic aspects of the engineering culture, those skills and attributes which were valued, had been explicitly discussed and manifested in practice. The diversity in ethnic, socio-economic and schooling backgrounds of the students, however, challenged implications of cohesion or shared cultural norms in a social sense, as exemplified in the comment:

> I think there is a culture in terms of "I am an engineer" and the way of thinking in terms of an academic attitude …but on a social level there isn't a distinctive social type, there is a distinctive thinking type (Angus, 1st year student)

Although these comments were taken from interviews in 1998, a strong sense of continued student affiliation is provided by the high level of retention, which continues to see more than 90% of first-year students proceeding to second year courses in engineering.

Future work and recommendations

For any degree program, it is useful to reflect not only on the strengths of the program, as this paper has done, but also on any areas of current or future weakness. The first-year program and the engineering program as a whole at the U of A, could be seen to provide students with an in-depth exposure to the engineering way of thinking and doing, but a counter opinion would posit that the program does not expose students to other disciplines, and their ways of thinking. This lack of breadth could be seen as a disadvantage when, as identified in the first paragraph, engineers of the future need to be "outward looking, globally aware and attuned to the real needs of communities". The disciplinary isolation of engineering students at the U of A is only partly alleviated by the inclusion of one General Education course, and currently approximately 20% of the students choose to complete a double or conjoint degree, usually combining Engineering with Commerce or Arts although other options are available.

A further area of future challenge may well be the gradual dissipation of the commonality of the "common" first-year. With calls for an expanding pool of applicants the likelihood of increasing diversity in the incoming cohort will require adaptation for both ends of a spectrum of ability. An Accelerated Pathway Program is already in place for those exceptionally able students who form the top 10% of the current intake. The need for "alternative pathways", particularly for students transferring from other institutions with credit, may also reduce the commonality of the "common" first-year.

Every program continues to evolve as staff, resources, structures and administration change and there will always be the need for reflection and refinement. The act of writing this paper, in itself provided an opportunity for discussion. The authors recognized that in focusing for the last three years on refining the content and delivery of individual courses in the new structure, it was timely to reflect on the bigger picture of the program as a whole. It seemed apparent, for example, that the current program may lack explicit integration particularly in relation to the development and introduction to professional skills and awareness of the profession. Even with the in-house nature of the program, and the explicit efforts to make connections to real life and between courses, it appeared that many students may still see their program as a collection of compartmentalized courses. Any review or reflection process appears to stimulate further questions, and for us, an awareness, will and enthusiasm has arisen to not only continue to deliver a first class program, but to seek answers to questions such as "How can we stimulate, encourage and enable students to structure their knowledge across course and disciplinary boundaries? Do our students identify themselves as student engineers rather than engineering students? How can we further aid that identity development?".

The work continues. The program, curricular and assessment innovations described in this paper for a well embedded, in-house first-year engineering program are offered as exemples of best practice to the community of engineering educators who recognize the importance of first-year programs, not only for retention, but for the development of student identity as an engineer .

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APPENDIX A

Course Prescriptions. Part I Bachelor of Engineering implemented 1996

Electrical Engineering Systems 2 points
The aim of this paper is to introduce students to typical Electrical and Electronic Engineering systems and technology. In particular the paper covers Power Systems, Control and Industrial Automation, Communication Systems and Microcomputer Systems. In addition, the paper will cover the fundamental electromagnetic and circuit theory principles required for the design and operation of such systems and technology.

Engineering Design 1 2 points
An introduction to engineering design, including: the role of an engineer in an enterprise, the nature of design and the design process, innovation and product development, written, oral and graphical communication. Exercises in the practice of design.

Engineering Mechanics 2 points
An introduction to mechanics including: planar forces, free body diagrams, planar equilibrium of rigid bodies, friction, distributed forces, internal forces, shear force and bending moment diagrams, simple stress and strain and associated material properties, kinematics and kinetics of particles, work and energy, motion of rigid bodies in a plane.

Materials Science 2 points
Atomic structure and bonding. Structure of Solids. Microstructure. Mechanical Properties. Alloying and Phase Diagrams. Engineering alloys and their heat-treatment. Engineering ceramics and glasses. Engineering polymers. Engineering Composites. Biomaterials. Electronic, optical, superconducting and magnetic materials. Corrosion and degradation of materials.

Mathematical Modelling 1 2 points
Brief introduction to mathematical modelling. Introduction to geometry and complex numbers. Functions and basic differentiation. Integration and solutions to simple differential equations, including numerical solutions. Application of the techniques through appropriate modelling examples. Vector and matrix algebra with physical interpretations.

Engineering Computing 1 point
Introduction to computing for engineers. Computer literacy, word processing, spreadsheets. Problem solving and programming using MATLAB package.

Environmental Principles 1 point

An introduction to environmental concepts and principles and their application to all engineering disciplines. Basic chemistry, physics and biology will be examined followed by environmental systems and the impact of engineering. Also covers mechanisms to avoid, remediate and mitigate human impacts on the environment and the place of these mechanisms in engineering design and management.

APPENDIX B

Course Prescriptions as at 2009 for Part I Bachelor of Engineering (Honours)

Mathematical Modelling 1 **15 points**

Introduction to mathematical modelling. Differentiation and integration (polynomials, trigonometric, exponential, logarithmic, hyperbolic and rational functions). Integration by parts, substitution and numerical integration. Differential equations and their solutions (including Euler's method). Complex numbers and roots of functions. Vector and matrix algebra, geometry, transformations, sets of linear equations, curve fittings. introduction to statistics and 'R'.

Electrical and Digital Systems **15 points**

An introduction to electrical, computer and electronic systems and technology. Digital circuits and analysis techniques, computer organization. Analog circuits and analysis techniques. Inductive power transfer, power systems and electric machines. Communication systems.

Materials Science **15 points**

Atomic structure and bonding. Structure of Solids. Microstructure. Mechanical Properties. Alloying and Phase Diagrams. Engineering alloys and their heat-treatment. Engineering ceramics and glasses. Engineering polymers. Engineering Composites. Biomaterials. Electronic materials. Corrosion and degradation of metals.

Introduction to Engineering Design **15 points**

The aim of the course is to develop an appreciation of design as a key aspect of professional engineering. Course elements: sketching and interpretation of engineering drawings; preparation of drawings using Computer Aided Design (CAD) software; design projects, some of which will require teamwork and cover design-build-test activities; an introduction to the engineering design process.

Engineering Mechanics **15 points**

An introduction to mechanics including: planar forces, free body diagrams, planar equilibrium of rigid bodies, friction, distributed forces, internal forces, shear force and bending moment diagrams, kinematics and kinetics of particles, work and energy, relative motion, kinematics and kinetics of rigid bodies in a plane.

Introduction to Engineering Computation and Software Development **15 points**

Introduction to problem solving in engineering through the use of the software package MATLAB and th high level programming language C.

Engineering Biology and Chemistry **15 points**

Introduction to chemical and biological systems. The application of engineering analysis and design techniques to facilitate understanding the multiscale structure, function and interactions of such systems. The use of research case studies to illustrate systems approaches to chemistry and biology.

English Language Competency **0 points**

To complete this course students must attain a level of competency in the English language as determined by the School of Engineering