

## A new, common, experiential 'Engineering Practice' course

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### SESSION

C1: Integration of theory and practice in the learning and teaching process

**CONTEXT** Throughout 2015 and 2016, the faculty of Engineering and Build Environment at the University of Newcastle re-envisaged the suite of engineering programs on offer to meet the future needs of students and society. One of the key areas addressed in these changes was to form a strong backbone of, our so called, professional practice courses running vertically through the programs. The foundation of this professional practice stream is 'ENGG1500 – Introduction to Engineering Practice'. This paper describes the implementation of this PBL course, the pitfalls and successes in the first offering of this new course.

**PURPOSE** This paper is to inform the engineering education community of our development of a new experiential learning first year course, and to provide details of the projects used for others considering the implementation of a project based introductory course. The ENGG1500 course aimed to give first year students an 'engineering experience' building excitement and thus increased engagement within their chosen degree, and contextualising the technical knowledge gained throughout the early stages of their program.

**APPROACH** The course was created as a common first year – first semester subject for all engineering students and was comprised of global lectures with discipline specific workshops. The workshops were the focus of this course, in which students completed a project, starting from an open question through to testing of a complete solution. Workshops predominantly operated as flipped classrooms encouraging students to work independently. The lectures were supplementary, containing information such as communication skills, problem solving and guest lectures from industry partners, to assist students with their projects and support technical learning in other subjects.

**RESULTS** The first offering of the course has been evaluated based upon formal and informal student feedback, attendance and student enthusiasm. Discipline specific projects, with interactive goals, generally produced high levels of engagement reflected by very high attendance in workshops. Some projects needed their difficulty increased as students requested additional work to do outside of scheduled class. Interestingly the lowest engagement was in the project using the most expensive and technologically advanced equipment; e.g. augmented reality. The engagement level of staff was seen to directly correlate with the success of the course, and senior students leaders provided strong engagement. Non-technical skills such as communication and teamwork were given relevance by relating them to the current projects, however the variations in projects lead to some discipline student groups feeling neglected when their project did not specifically relate to the lecture material.

**CONCLUSIONS** Semester long project based learning is an effective tool for building an engaging first year engineering course. Tangible projects and invested staff are required this process to be successful. Above a threshold, monetary investment into project equipment does not appear to correlate with student engagement.

### KEYWORDS

Experiential learning, first year engineering, PBL

## Introduction

This paper discusses the development, first delivery, and initial outcomes of a project based learning course, designed to build engagement in the University of Newcastle (UoN) engineering degrees. Whilst not a novel concept in engineering education, this paper is intended to add additional learning objects (projects) to the public domain and report on the personal learnings achieved in the development and deployment of this course.

This course was developed as part of the reimagined engineering programs commencing their roll out from Semester 1, 2017. These eight new engineering programs were centred around the aspiration of a degree “for their world not ours” and involved completely rebuilding many of our courses which had traditional teaching styles and content, and replacing them with new courses which embraced novel learning techniques appropriate for the new world engineer. One aspect of the new programs was the creation of 4 cohesive, core, ‘Professional Practice’ courses as a vertical spine throughout the degree programs. These 4 courses replaced the existing Introduction to Engineering Practice, Applied Ethics, Engineering project Management. These new Introduction to Professional Practice, Sustainable Engineering Practice, Managing engineering Projects and Engineering Complexity courses were designed as completely new courses with no material carry over from the predecessors.

The University of Newcastle’s pre-2017 engineering programs used a common ‘GENG1803 - Introduction to Engineering Practice’ course which was introduced in 2005. Originally located in semester 2, it was moved to semester 1 due to pedagogical needs associated with other technical courses in 2009, however its curriculum was not substantially updated to reflect the inherent change in student capability. The intent of GENG1803 was to introduce students to the engineering degree as a whole, contextualise the knowledge they learn in other subjects, and teach non-technical skills such as communication. This was originally achieved, in part, through the Engineers Without Borders (EWB) challenge. Though in recent years custom in house projects became normal. Student feedback for GENG1803 often performed less than ideally. One common complaint of the students centred on a dislike of, or far more commonly a disinterest in, the projects.

We herein present knowledge gained from our new first year Introduction to Profession Practice course, ENGG1500 to aid others pursuing a similar endeavour. Simply put the course was designed to build engagement with the students. To achieve this we selected and created projects for a project/problem based learning (PBL) delivery model. We utilised a single, semester long, student project to drive learning rather than dictating learning through lecture delivered material. To be successful in this form, we argue that it is important that the problem needs to be complex enough to keep students working throughout the entire semester, yet approachable enough for students, at least in part, to control the way in which they solve the problem.

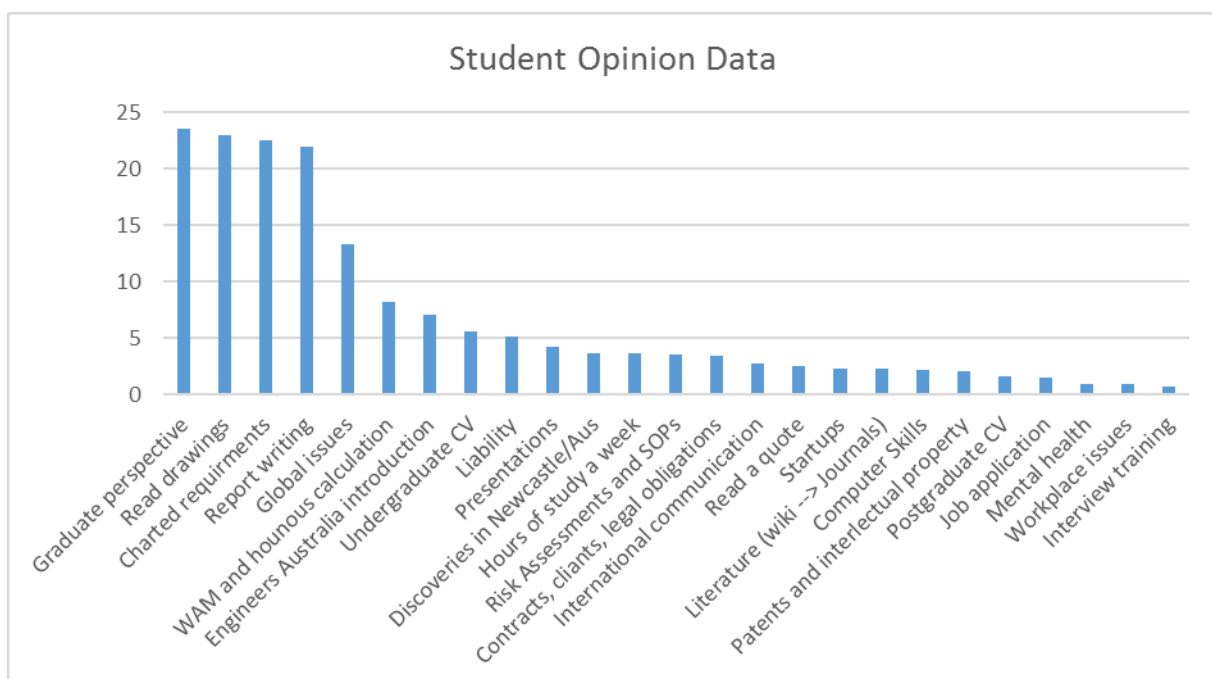
While PBL had been shown to be successful at many other institutions it was a relatively underutilised teaching method at the University of Newcastle in the Engineering schools, especially in the general units. Preliminary discussion and research into PBL were frustrated by a lack of applicable information to the specific intents for our first year engineering course at the University of Newcastle. Contradictory opinions were common amongst staff contacted at our Centre for Teaching and Learning, other academics contacted across Australia, and Teaching practices known to be effective within our own school. Additionally, the reported successful practices of others often appeared impractical in the context of ENGG1500. The common exemplar being Olin College, who run an incredibly successful PBL engineering degree for very top academic students in the United States, and we anticipate on a far larger budget than the University of Newcastle was able to provide. Other examples such as the University of Illinois at Urbana-Champaign with a much smaller budget and more diverse student body, are more applicable but still not, in our view, directly translatable. During initial

development work, an external education consultant was engaged. However they were released as it became clear the development needed in-house experience and commitment. Although there is considerable research available on PBL, distilling relevant information became critical. Our overall assessment from the literature, discussions and early development work lead us to conclude that this course would be custom built and tailored to the specific university to work most effectively.

The University of Newcastle has several identifying traits. 34% of our student are low socioeconomic status, many students are their first in family to attend a university and, Newcastle has a strong mining and industry backbone. The University of Newcastle has approximately 40 000 students with the 2017 intake into the new engineering program being just over 400 students. The engineering programs at Newcastle have historically performed well across many metrics.

## Development

As part of the development phase, we engaged with students across our engineering facility to gain their collective insight. A voluntary, hard copy, 4-page survey was created, with long answer questions directly related to the previous GENG1803 course and a series of Yes/No questions (with optional comment areas) related to topics that might be included in the new course. The survey was deployed within a second semester first year course (for a reactive response from students that had 'just' completed GENG1803), and a third year course (to gain a more reflective perspective). A return rate of ~85% was obtained indicative of a strongly engaged student group. The results from the Yes/No questions of the first year students are displayed in Figure 1 where the ratios of Yes: No are plotted. There is an overwhelming number of ratios greater than 1, all but the lowest 3. The strong desire to learn the so called "soft skills" was exemplified by an overwhelming desire from students to be taught report writing, despite report writing courses historically receiving poor student feedback. This information was used in the initial stages to dispel some of the assumptions of our academics surrounding the course content. It is important to recognise that this is student opinion data only, and was not the only metric used for designing the course. It served to highlight that "soft skills" are not inherently disliked topics but the way in which they are presented is critical for student engagement.



**FIGURE 1** Collation of 1<sup>st</sup> year student input illustrating what they rated highly, and what they were less interested in.

## Structure

ENGG1500 was designed and timetabled with the focus on a 2 hour discipline specific project based workshop session, supplemented by a common lecture session and an unstaffed tutorial each week. Students completed their projects during the workshop sessions and these classes were controlled and taught by individual disciplines. In some weeks, the workshop time was utilised as project specific lectures by the supporting staff, other weeks as tutorial time, with the remainder as open time for students to work on their projects: most disciplines used different styles throughout the year as the individual projects demanded.

The unstaffed tutorials were simply created as an empty timeslot in the student's timetable. It was intended that students would work on their reports with the objective that this would reduce students 'leaving it to the last minute'. This aspect did not work, and was not appreciated by the student body as was indicated in the student's qualitative feedback.

## Project development

The majority of the development work was centred on creating an engaging and relevant project for the students. We anchored the project as the cornerstone of the course and the key aspect for each project was an interactive outcome. That is, something that the student teams could demonstrate on test day and show to friends and family at the end of the course. Six discipline specific projects ran simultaneously throughout the course, summarised in Table 1. Interestingly the Electrical and Mechatronics projects, developed separately, independently converged on similar outcomes, and were eventually coalesced.

Projects were generally designed in close contact with, or by, discipline specific experts. We identified a suitable expert within each discipline, and engaged them with a brief for the collaborative design of a suitable project and worked closely with the course co-ordinator to produce a project that was based on core discipline knowledge.

Three of the six projects were co-developed by senior undergraduate students over the preceding summer break, with support from a staff member. This process proved remarkably successful as these senior undergraduate students were highly motivated and focused. These students also provided curriculum scaffold information relevant to their field of study as they were still actively undertaking their studies.

The Micro Wind Turbine project was designed by PhD students from the University of Newcastle's mechanical engineering wind turbine research group. These PhD students showed a similar enthusiasm towards teaching to the other senior undergraduates and their expert knowledge enabled them to develop appropriate course content for first year students in the relatively complex field of fluid dynamics. A large 'value add' for this mechanical project was student access to various wind turbine assemblies that the group has created and actively use for their research. This PhD inspired project, ensured that the students had a tangible real-world application in view, preventing the project from appearing like 'a high school project'. A competition emerged on the testing day to see which undergraduate groups could get closest to the PhD exemplar turbines.

By way of contrast, some disciplines were unable to identify suitable 'summer students' and academics were unable to commit the required time for good project development. This resulted in these projects being created and led by the course coordinator, who did not have a background in these disciplines. As a result these projects lacked the strength of the discipline connection observed in the other projects. The staff tasked to run these workshops demonstrated no ownership of the content, which was apparent to both students and other staff. These projects created the largest (and disproportionate) workload for the course coordinator throughout the semester, with the additional efforts required to try and generate student engagement for these disciplines.

**Table 1 Discipline specific projects used in ENGG1500**

<b>Project name</b>	<b>Key tasks covered</b>	<b>Disciplines</b>
Micro Wind Turbine	Designed and build a micro wind turbines using a supplied generator and \$100 budget.	Mechanical
Semi-Autonomous Vehicle	Assemble and program an Arduino controlled vehicle to navigate an obstacle course. Most hardware is supplied.	Electrical/ Mechatronics/ Computer systems
21 <sup>st</sup> Century Lecture App	Created an app using MIT app inventor which allowed students to “check in” to lectures and interact with the lecturer.	Software
Solar Desalination	Convert salt (sea) water to drinkable water mainly using solar power with a \$100 budget and 1 m <sup>3</sup> space.	Chemical
Water Tower	Design and build a 10:1 scale water tower, supporting 50 L of water 1.25 m above the ground with a \$100 budget.	Civil
Augmented Reality Simulation	Design a river crossing by creating specific terrain (university grounds) in augmented reality and simulating flood conditions.	Surveying/ Environmental

### **Use of Global Lectures (in this PBL course)**

A challenge resulting from the highly independent nature of each project was that it became impossible to provide global lecture material of immediate value to each project group. This pushed more emphasis on the workshop sessions to cover all project specific information. Global lecture material was therefore developed to provide interest and relevance, encouraging student attendance. No content in these sessions was directly assessable. Despite this challenge, it enabled material to be presented which ordinarily would not fit into a course. For example, engineering problem solving ethos, program honours calculation, creation of models and the implicit assumptions made, research topics of the university's academics and relationships between current courses and future course all became lecture content. This ‘orientation’ content was created partly from the aforementioned survey, partly from asking senior students “what do you wish someone told you in first year?”, and from asking other academics “What (general knowledge) would you like your students knew before they came to your class?”.

The global lecture material also initiated our planned program long written communication skills taught and reinforced throughout our Professional Practice stream. This initial introduction to technical writing focused on ‘why we write’ rather than ‘how to write’ with large focus on understanding the target audience, and how the audience will influence the writing style. Consequently the first ENGG1500 assessment task involved writing a report “for another ENGG1500 student from another discipline”, and the second linked task was to proofread, edit, and grade 4 of those reports. Concepts such as concise wording and appropriate language were reinforced through exemplars of technical writing, in the form of research publications, PhD and Honours theses.

### **Physical Development challenges**

The practical nature of the course required non-traditional learning spaces and a volume of physical hardware to be designed, constructed and/or commissioned. The lack of suitable space during the early developmental phase of the course greatly frustrated project design. Despite the University and Faculty having several discrete groups of support staff, all of which should have contributed to the development of the course, one disciplines team

voluntarily took ownership of ENGG1500 and completed the work required to ensure timely delivery. Without that 'buy in' from that one technical group, the outcome for this course would have been severely compromised. As a learning outcome for academics planning to pursue this type of course development, ensuring that the technical/supporting staff have a complete understanding of the requirements and deadlines is critical. This was achieved by involving them in the planning and course design several months before the start of semester.

## Delivery

As with the design of the projects, senior students also did a large proportion of the demonstrating, with academic mentoring and support through the course-coordinator as needed. Senior students managed three entire projects containing approximately 75% of the student cohort. We believe that these projects were all highly successful due to the positive attitude of these senior student demonstrators, towards both the specific project and the practice of education. As these students were involved during the development of the project they felt a strong sense of ownership and were heavily invested in its success. The first year students readily picked up the enthusiasm of the workshop leaders and carried it throughout the project. Senior students adapted well to the novel teaching strategies of problem based learning, encouraging students to drive the project forward, supporting and advising when needed.

This was in direct contrast to some of workshops run by full time academic staff which suffered from a distinct lack of engagement by both staff and students. This resulted in little imagination and creative thinking in the solutions that the students produced, undermining a main goal the course.

A large difficulty for the course coordinator was a lack of expertise across some discipline areas, which caused a heavily reliance on the workshop leaders. However keeping abreast of all projects was essential for the course as a whole to run smoothly. This led to effectively coordinating 6 separate discipline specific courses as well as the course as a whole.

Unsurprisingly the hours required were excessive. During the initial and final weeks of the course over 15 hours of face to face time with students was common and test week required approximately 25 hours of face to face contact. Despite the taxing nature of so much face to face time, as well as maintaining an open door policy, it was felt essential to establish a strong rapport with the students for the course to succeed, and for the general success of the students. The workload is expected to decrease as the course matures, however it is believed this type of course will always be time intensive to run optimally.

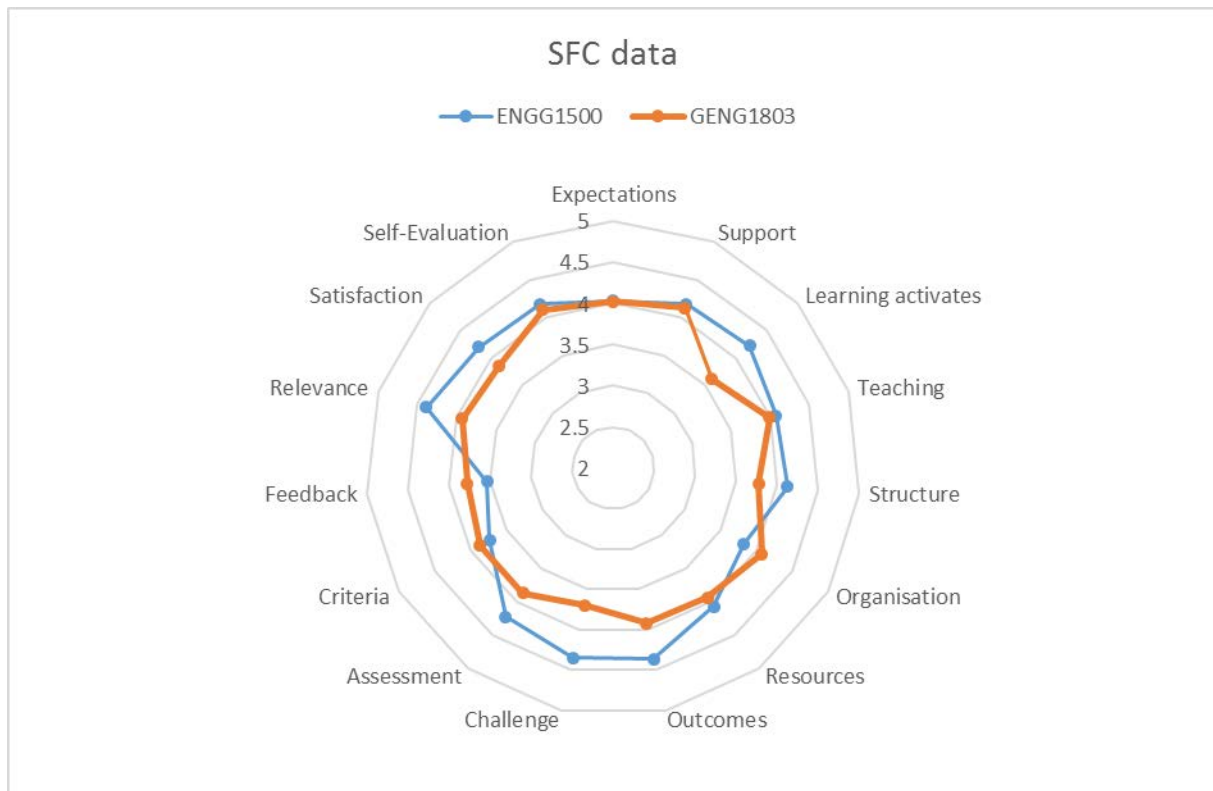
## Outcomes

The courses first offering was in semester 1 2017, and analysis of the course has been performed using formal student feedback, discussions with students and tutors as well as monitoring attendance and performance in workshops.

The formal Student feedback on course results are displayed in Figure 2. Overall the course performed well, with between good and very good levels of student satisfaction across most areas. The course performed relatively poorly in 'Organisation' partly due to the dynamic nature of assignment briefs and partly the fluid assessment due dates, mainly attributed to it being the first offering of the course. A single assignment outline was issued covering all projects, this caused some confusion as sections were not equally applicable to all disciplines and projects, as a result of this we believe that the 'Criteria and Expectations' metric in our student feedback suffered. This was corrected for the final assessment by having a general section, and then a discipline specific section. Due the open ended nature of the course, assessment tasks were intentionally kept broad to encourage creative thinking and prevent students working to a rubric. This resulted in some confusion, but greatly

improved the creativity displayed in the projects and challenged the students to think independently.

As can be seen in Figure 2 Assessment Feedback was by far the lowest scoring category. This was largely due to a perceived extended time to return assessments in the Semi-Autonomous Vehicle project. A single marker was used for all autonomous vehicle submissions for homogeneity of grades and feedback. This marker needed to meet other time demands and whilst meeting the University policy target for the return of assessments, resulted in delayed feedback compared to the other project groups.



**Figure 2 Student feedback on courses data**

The numerical data itself is separable into student program codes enabling investigation into feedback from specific programs. Whilst overall this proved relatively unhelpful in identifying areas of improvement, it did allow for an interesting observation. In some cases, multiple program codes did exactly the same project, and so conceivable should have given identical feedback, however the data shows drastic differences. Three different programs groups, Electrical (in teach out), Electrical & Electronics, and Mechatronics all completed the Semi-Autonomous Vehicle project. Picking apart their student feedback numerical results demonstrated a maximum spread of 1.33 (i.e. 2.20 to 3.53) in the Feedback category. A better understanding of course performance was gained through face to face discussions with students and their comments within the Student feedback instrument.

Students lecture attendance remained high throughout the semester. Many students embraced the idea of seeing how other disciplines think whilst some were disinterested by the general nature of the lectures. Student comments generally attributed the lecture enjoyment to the positive attitude and presenting style of the lecturer rather than the specific content. The young age of the lecturer (28) helped in empathising with the students, building trust and creating a positive atmosphere, however it did prevent this academic from speaking with authority on certain topics which require experience. To compensate guest lectures from

experienced personal, though not necessarily academics, on; creative thinking, employability, life as an engineer, mental health and the role of OH&S were highly successful in keeping lectures interesting to the general cohort. Attendance in workshops was universally high, despite being them being ungraded. Most workshops achieved above 80% attendance most weeks and regularly 100%. Some projects, the Semi-Autonomous Vehicle project in particular, saw students regularly requesting more access to the workshop room to continue working on their projects outside of scheduled classes. Some teams progressed so far in advance of the original project description that the difficulty of the project was twice increased, to keep the motivated students challenged.

When considering overall student engagement and satisfaction there was no correlation to the expense of a project. The Augmented Reality project was the most expensive yet had the lowest engagement, whereas the tighter budget design and build projects (\$100 per group of 4 students) performed well. No feedback was given implying spending more money would significantly improve the projects. That said, allocation of space, refurbishment of rooms and purchasing of general workshop equipment was critical for the course to run effectively. Our assessment is that it appears there is a minimum requirement to create a meaningful project, but above this minimum, diminishing returns are seen. A better return on investment is likely from hiring additional/better staff rather than into more elaborate equipment.

It is highly evident, that for a success implementation a committed champion for each project is required. It was also apparent that a custom project designed in house was an effective method of performing project based learning whereas adopting a project from elsewhere, led to lack of ownership. This was exemplified by the successful senior student created and lead projects vs the course co-ordinator designed augmented reality project.

'Test day' was critically important for student engagement and satisfaction. The vast majority of students were greatly excited by testing their finished products and evidently proud of their results. Students were driven to produce the best product they could with many additional workshops running in the final weeks to satisfy the extra time and effort the students wanted to apply. The final lecture (the week after 'testing week') was predominantly devoted to discussion and demonstration of projects. Videos and photos taken during test week were shown and the 21<sup>st</sup> Century Lecture App was actually deployed in the lecture. If measured by applause, this lecture appeared to generate the highest level of engagement of the whole course.

Resulting from teaching 'why' and not 'how' engineers write, saw an increase in student opinion on the importance of writing and a deeper understanding of the underlying principles. However, it also lead to some obviously poor writing practices. For example, heavy use of colloquial language and poor understanding of how to write an abstract perpetuated through the entire course. Some disciples saw the lack of teaching a formal writing style detract from the quality of the reports while others saw it improve. This is one area for reconsideration in 2018, both with the ENGG1500 curriculum, and the teaching staff associated with the course.

Whilst anecdotal, there appears to have been an apparent increase in total program retention in for students enrolled in ENGG1500 compared to the previous years retention data. Whilst small, and from a single measurement, the first semester program attritions reduced by 3%. At an individual course level, the withdrawal rate reduced by approximately 1/3 of the 'norm' for past offerings of GENG1803. These are currently simply correlations, without substantive direct data, and the decision for any student to remain in a degree is influenced by a great number of factors. However, it appears that this is a positive result for the course.

## **Observations, Intentions and Potential Improvements**

We argue that in order for PBL to be fully utilised the projects needed to be open ended so that multiple solutions could be equally effective. This allowed for creative problem solving to truly flourish, opposed to the more prescribed 'standards-driven' design typical of later, more



technical courses. However, unstructured workshops where students were given freedoms, lead to general confusion and inefficient workflow, especially in the first weeks of university. Students would often fixate on their first solution, and be unwilling to attempt anything new. Ironically projects which had a more structured initial stage, slowly encouraging students to become self-sufficient were more productive. Consequently the second iteration of the course may structure the first 4 weeks and have a small assessment in week 5. Completing this initial assessment task should develop the skills the students need to approach the bigger problem, generate confidence and lead to more creative solutions.

The unstaffed tutorial times did not have their desired effect, as they were not linked to the rest of the course. This was due a timetable issue that could not be resolved before enrolments opened. Restructuring of the tutorial times into open help session available to all student but staffed by discipline specific workshop leaders will be trialled in 2018 as a way of giving students more time to ask questions and receive feedback on their assessments.

Some of the earlier assessments will be rewritten in a format similar to the final assessment, with each having a general section and a discipline specific section. This is intended to remove some of the confusion for students, and allow the disciplines to better prepare their own students for what will be required of them in their reports for future courses. It is also evident that a considerably larger allocation of marking hours is required to improve the written feedback on reports.

The technical writing aspect of the course, while not poorly received, was insufficient. More time and focus needs to be placed on this area. It is intended that more lecture time will be spent on this, and it is also possible that each workshop will spend a session discussing discipline specific writing styles and providing feedback on reports.

Some staff will be replaced in the projects which suffered from poor staff engagement. It was obvious that staff need to be involved with the course many months prior to its start date. Initial meetings with new staff are happening approximately 6 months before the course will run again. Senior students will be investigated to be part of all projects.

2018 will see the introduction of the new Medical engineering degree at the University of Newcastle, and the new discipline will require its own project. This presents a unique problem in the complete absence of any current Medical engineering staff or students.

## Conclusions

The University of Newcastle offered a new general first-year, problem based learning course in 2017. Student engagement and satisfaction was greatly increased over the previous introductory course.

Discipline specific tangible projects that were assessed on 'Test Day' in the second last week of semester proved crucial to the positive outcome of the course.

Workshop staff were instrumental in both course development and delivery of projects, with undergraduate and postgraduate students completing the majority of the work with excellent results.

Lectures became secondary in importance to workshops and careful attention was required to keep them interesting to maintain attendance.

Students enrolled in similar programs, completing the same project, receiving assignment feedback from one common marker, at the same point in time, provided statistically significant different student feedback scores on the student feedback of courses, 'assessment' scale. This suggests that investigating the difference between different discipline projects numerical variance in their qualitative student feedback, is likely to be heavily confounded.