Volunteering for success: strategic design and implementation of the Icarus Program

Introduction

Engineering education at large public institutions has remained largely unchanged since the 1950s (Dym, 2004). This model of education has a strong theoretical focus and thus typically consists of a large number of compulsory “engineering science” courses in the 1st to 3rd years of curriculum, before progressing to elective and capstone courses in the 4th year (Dutson, Todd, Magleby, & Sorensen, 1997). The graduates of these programs have been perceived by industry to be poorly prepared for practice, i.e. the focus on theoretical knowledge has come at the expense of practical knowledge needed to perform in industry (Dutson et al., 1997).

In response to these claims, initiatives to reassert practical skills in the form of first year programs (Vallim, Farines, & Cury, 2006), capstone design courses (Fox, Weckler, & Thomas, 2015), and problem based learning environments (Dym, Agogino, Eris, Frey, & Leifer, 2005) have all been implemented, with varying degrees of success seen in terms of balancing theoretical and practical curriculum components. However in the context of large-cohort courses seen in most modern Australian engineering programs, these initiatives can take years to successfully implement, troubleshoot, and subsequently quantify curriculum improvements. The capacity for rapid piloting of education initiatives is thus diminished.

Linked to the program-level considerations for implementation of curricular education initiatives is the need for consideration of course-level practicalities such as student assessment and staff time allocation. Both of these are inherently subject to strong external factors. For student assessment, external factors exist in the form of imposed deadlines and directives, pressured evaluation, and a perceived link between grades and career opportunities. For staff time allocation, external factors exist in the form of complicated and changeable university expectations around staff performance, particularly as related to teaching, research, and service expectations for career progression. Staff and students under such external coercions will tend towards extrinsic rather than intrinsic motivational behaviour (Ryan & Deci, 2000). There is thus an unwillingness to engage in an activity for its inherent value, which, combined with the program-level considerations, make piloting of education initiatives and/or drastic curricular change a Sisyphean task.

This paper outlines the iterative development cycle that preceded a recent implantation of the Icarus Program, an initiative within the School of Civil Engineering (SoCE) at the University of Queensland. The primary goal of Icarus was to intrinsically motivate students and staff to develop and engage in educational opportunities outside of the existing curriculum. This paper outlines four phases of program development and the responses of staff involved that ultimately led to the creation of the program in its current form.

Model 1: Course-level model to increase intrinsic student motivation

Description

Model 1 was a modification to the first year program with a view to changing course components to increase intrinsic student motivations. Specifically, a primary consideration of the Model 1 was to increase the student choice and the opportunity for self-direction at a course level, both of which have been found to increase intrinsic motivation (Deci & Ryan, 1985) and directly generate desirable engineering graduate characteristics such as increased learning and creativity (Ryan & Deci, 2000) capabilities. The style of first year course resemble many other around the world, containing an introduction to the design process, a series of deliverables accompanying each stage of design, the fabrication of a prototype, and a test of its performance.

Model 1 proposed that students experience several areas of engineering through a series of 4 week long modules. The modules were to be spread across two semester-long courses, with three 4-week modules each. Course 1 was titled *"Engineering Everything"* and was designed to help students develop an understanding of their purpose for studying engineering and showcase possible study and career paths they might undertake. The first module was outlined with the following schedule:

- *Week 1: Orientation.* Welcome to students, overview of course and Bachelor of Engineering program, and an initial survey of student interests and motivation to study engineering.
- *Week 2: Study Paths (short-term goals).* Presentations by a series of 2nd to 5th year students about themselves, their study path, and their co- and extra-curricular engagements. Talks would be recorded and made available to all engineering students through the program website.
- *Week 3: Career Paths (long-term goals).* Presentations by a series professional speakers chosen to represent broad range of professions including engineering industry, academia, public service, entrepreneurship and business, management of small and large companies, site and design engineers, etc. Talks were be recorded and made available to all engineering students through the program website.
- *Week 4: Class Analysis and Project Introduction.* Results of Week 1 survey are disseminated to give individuals insight into their learning and motivation styles. The implications of the results and mini-project selection to be discussed.

Assessment for Module 1 would be based on completion of a minimum number of supplemental videos or lessons. The number of students who view extra videos would serve as an indicator of interest within the cohort and serve as a guide for the development of mini-projects and other supplemental educational activities. Modules 2 and 3 would then be four-week mini-projects. Students complete one group project and one individual project to receive credit for the course.

Course 2 followed course 1 and was entitled "*Design and Future Thinking.*" The focus of this course would be to advance the students technical competence through design- and research-based projects that highlight the technical competence necessary to progress in their areas of interest as identified during the first semester course.

Response

On presentation to staff within SoCE, Model 1 received near-unanimous feedback that the major barrier to implementation would be that of program jurisdiction. The SoCE program components encompassed 2nd to 4th year courses, with 1st year program components developed and taught by Faculty to ensure flexibility in choice of engineering specialisation in later years. Model 1 therefore would require both an increase teaching responsibilities and the need to lobby for an increased jurisdiction and control of 1st year program components.

Any improvements to student motivation in Model 1 would thus come at the expense of staff motivation in terms of time allocation pressures and so Model 1 was deemed inadequate.

Model 2: Curriculum-level Model to modify teaching distribution

Description

Given the teaching concerns expressed by the staff during the Model 1 pitch, a second model was proposed based on even allocation of students to each staff member. The student-to-staff ratio for the program was 16 to 1 and so Model 2 proposed that each academic could be responsible for introducing and assessing all content knowledge for 16 students. The benefits of this model would be the elimination of all large lecture-based courses and allow for a smaller classroom experience. The need to have a single academic cover all of the content for a given semester necessitated a reduction in the total amount of content covered in the program, achieved through the combination of existing courses and the reallocation of existing compulsory courses to elective status.

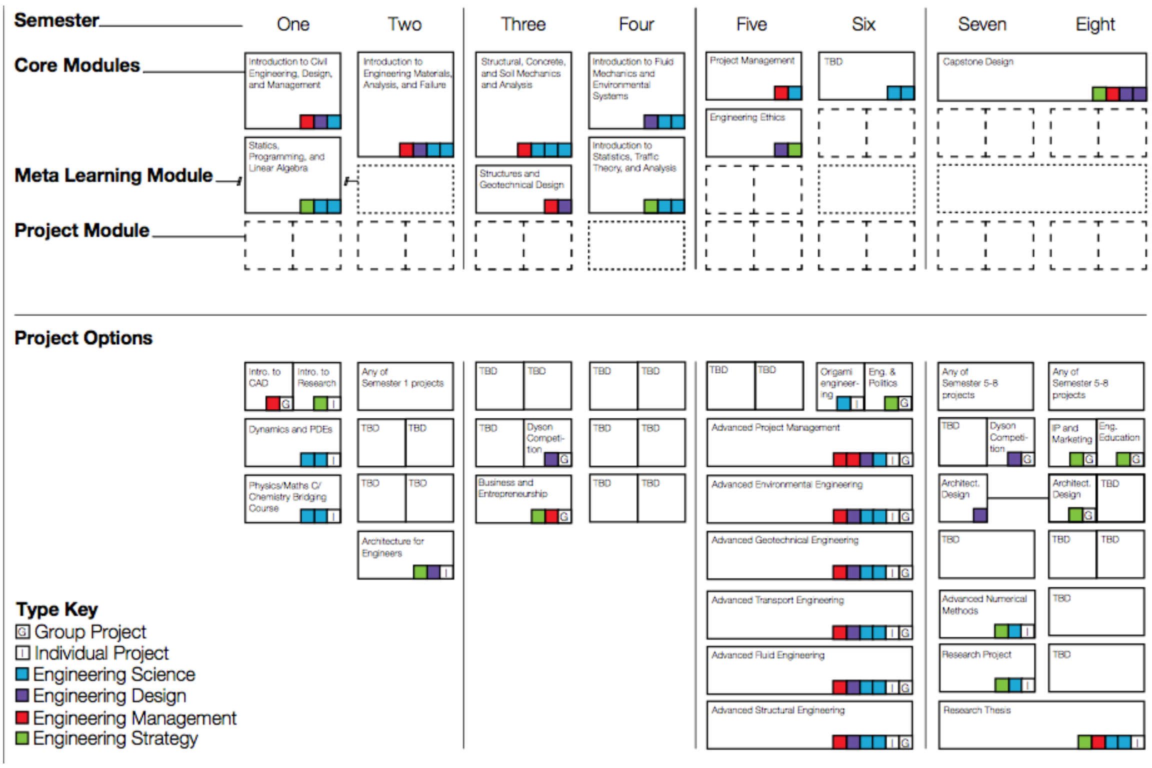

Figure 1: Model 2 Program Outline

Figure 1 illustrates the proposed Model 2, which drastically restructured the curriculum through the integration of existing courses and the removal of several required courses in place of electives. An example can be seen in semester one with the integration of statics, linear algebra, and computer programming. This logical integration of content was aimed at reducing the total number of courses required by combining topics with overlapping or complementary areas of knowledge.

Response

Feedback on Model 2 showed that the idea of focusing teaching energy on a smaller group of students was attractive, however some academics were uncomfortable rescinding their influence over their area of expertise or teaching new content in which they had no prior experience. Additionally, the ability to completely restructure the program to have fewer courses and a greater influence on design-based education was not a widely favoured model. The belief that students would lack some of the theoretical foundation necessary to contribute to a design project of sufficient complexity was a primary concern.

Model 3: Curriculum level model with parallel courses

Description

The first two models showed a willingness in staff to engage with smaller student groups, but only if it was perceived to maintain or reduce workload. Model 3 was thus developed to focus on 2nd year courses and so better align with the current teaching activities of School staff. It proposed that a group of students could be selected from the three 2nd year compulsory subjects and taught with modified content or pedagogies, for example, a design-based education compared to a traditional “engineering science” course (i.e. lecture, homework, and exam). In this way, outcomes of the two groups could be compared immediately for rapid feedback on efficacy of curriculum changes.

Response

Two issues arose from feedback on Model 3: equity and consensus. Equity concerns were raised with respect to students in parallel course offerings: any curricular changes should be made available to all students or no students, lest one offering advantage/disadvantage a portion of students. Consensus concerns arose from disagreements as to what changes should be piloted within parallel course streams, or if any such curriculum changes were needed at all. Such disagreements would forestall the ability to test changes in courses taught by different staff members.

Model 4 (Icarus): Co-curricular project model to compliment curricular courses

Description

A final model was arrived at through synthesis of the well-received aspects of Models 1 to 3:

- Model 1: generate student awareness of a diversity of civil engineering disciplines and intrinsically motivate them with a project that appeals to their specific interests.
- Model 2: engage academic mentors with a small team of students in a topic of their core expertise, such that this engagement is not a substantial demand on their time.
- Model 3: offer opportunities for motivated students to pursue in addition to, rather than in place of, their compulsory courses.

Model 4, the Icarus Program, was thus implemented as a pilot co-curricular program and received wide agreement and support from the School staff. By focusing strictly on co-curricular efforts, many of the goals of the Icarus ideology could be implemented immediately. A survey of current interests and expertise of School staff found four projects that could be structured to compliment the three compulsory courses 2nd year civil engineering courses. Courses and Icarus projects are listed in Table 1.

Table 1: Icarus Projects S1 2015

Course	**Icarus Project**	**Focus**
Structural Mechanics	Festi Flat	Transitional Shelter Development and Origami
Introduction to Transportation Engineering	Station Simulation	Virtual Reality Transport Simulation
Structural Mechanics	Tianjin TOMMBot	Origami and Robotics
Environmental Issues, Monitoring & Assessment	Turbidity Challenge	Water Quality Surveying of Moreton Bay

Projects were also intentionally selected to be very different in nature: Station Simulation closely resembled a software course, Festi Flat resembled an entry-level design project, Tianjin TOMMBot was an international collaboration across disciplines and universities, and a Turbidity Challenge resembled an honours or post-graduate research project.

Results of Pilot Implementation

The projects were advertised as optional, volunteer-based projects and not directly linked to any form of academic credit. In its first semester of implementation, the Icarus Program received 64 applications from a cohort of 261 students. Figure 3 illustrates the demographics of the applicants included 52/48% male/female ratio, students from 6 continents, and a broad distribution across GPA bands and project preferences.

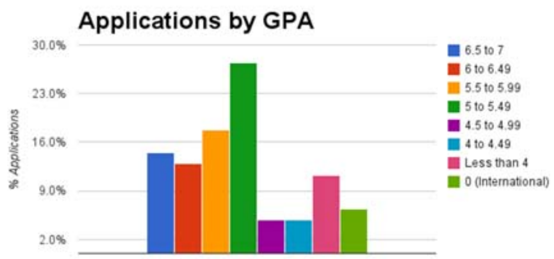

Figure 2: Project Preferences and Applicant GPA Distribution

Strong project activity was maintained throughout the first semester, with all projects achieving their respective objectives. A second semester implementation of Icarus was then offered, with a near 100% reapplication rate from students that completed the first Icarus semester. The mentors of semester one projects each offered twice the number of projects in semester two. Additional mentor interest also enabled an expansion to 19 projects and 19 mentors (out of 28 staff members), without any strong advertisement or inducement from the Icarus coordinators or University. Student applications were received across years and Schools and mentorship applications were received from industry partners and other Schools.

Conclusion and Future Work

The goal of this paper was to outline an example of educational reform focused on increasing the intrinsic motivation of students and staff at a large Australian university. While this paper does not directly measure intrinsic motivation quantitatively, the large uptake, retention, and rapid self-growth of staff and students in the Icarus program suggests that this has been achieved to a large extent. The fact that enrolment is distributed across an array of specialties and student groups is also a very positive sign. By outlining the development process that led to the final and successful Icarus implementation, it is hoped that other academics wishing to implement similar programs at their universities will have some shared experience to draw from.

With the rapid growth of the Icarus program in such a short period of time, it is still unknown to what the extent to intrinsic motivation was achieved or which specific aspects of Icarus were beneficial in achieving this. Assessment of the outcomes of the program in these areas is ongoing. Furthermore, with so many variables at play including the composition of individual projects, mentor and team dynamics, and different expectations as set by students and staff, there is much work to be done to conclusively identify what exactly is happening in this co-curricular space. Besides students' direct experience within the Icarus Program, further work needs to be done with regards to whether or not participation impacts student experience more broadly as engineering students. This work is also currently under way.

References

Deci, E. L., & Ryan, R. M. (1985). Intrinsic motivation and self-determination in human behaviour. New York: Plenum.

Dutson, A. J., Todd, R. H., Magleby, S. P., and Sorensen, C. D., "A Review of Literature on Teaching Design Through Project-Oriented Capstone Courses," Journal of Engineering Education, Vol. 76, No. 1, 1997, pp. 17-28.

Dym, C. L., "Design, Systems, and Engineering Education," International Journal of Engineering Education, Vol. 20, No. 3, 2004, pp. 305-312.

Dym, C. L., Agogino, A. M., Eris, O., Frey, D. D., & Leifer, L. J., (2005). Engineering design thinking, teaching, and learning. Journal of Engineering Education, 94(1), pp. 103-120.

Fox, G. A., Weckler, P., & Thomas, D. (2015). Linking first-year and senior engineering design teams: Engaging early academic career students in engineering design. Advances in Engineering Education. 4(3), Pp. 1-14.

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. American Psychologist, 55(1) 68-78.

Vallim, M. B. R., Farines, J., & Cury, J. E. R. (2006). Practicing engineering in a freshman introductory course. IEEE Transactions on Education, 49(1). doi: 10.1109/TE.2005.856157

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