

## Engineering Students or Student Engineers?

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***Abstract:** This paper reports on an innovative unit that embeds the acquisition of communication and professional skills into a technically based project. The project revolves around two engineering artefacts: a popsicle-stick bridge and a mousetrap-powered car. The design and construction of each artefact are conducted by different teams of students – each team designs a bridge and constructs a car, or vice versa. The core principle behind this approach is requiring the students to act as Student Engineers, rather than as engineering students. Requiring students to work both as designers and constructors introduces them to the different communication requirements of each role. More powerfully, they also portray the role of the clients for each others' engineering project, providing a valuable alternative perspective. The project has led to significant improvements in students' communication skills as well as their development of their identities as professional engineers.*

### Introduction

The requirements of an engineering degree program are many and varied, but ultimately the core mission is simple - transform a high school leaver into a graduate engineer in four years. An increasingly diverse entering student cohort has complicated this mission over recent years, as well as increased demands from employers – now we deal with a journey where both the start and end points vary from student to student.

One of the seldom-questioned complications of an undergraduate engineering education is that it occurs at a University, rather than in an engineering workplace. This is in contrast to trade apprenticeships, such as plumbers or electricians, who receive a large part of their training in the workplace in which they are intending to work. This dislocation means that an engineering student is subject to an additional transition – the transition from high school student to engineering student as they start their degree, and the transition from engineering student to engineer as they complete their degree.

Authenticity is widely acknowledged as a key aspect of an effective learning environment (Zemelman *et al.* 1993). New learning is dependent upon the prior learning in which it is anchored (Ausubel 2000), and situating the learning of engineering in a university context has consequences for the way in which the students learn. There are a range of behaviours that are commonplace and implicitly accepted in universities – such as absenteeism, late submission of work, collusion and plagiarism – that are completely unacceptable in the professional engineering context.

Engineering students acquire a wide range of competencies throughout their degree, not all of which are deliberately intended as part of the curriculum. Some of these “accidental competencies” (Walther *et al.* 2007) such as students learning to bargain across power differentials as they question the mark they received for an assignment, are very useful. Many of these – such as the “student” behaviours of cramming for exams, avoiding deadlines etc – are detrimental to their development as an engineer. Whilst very useful for the four years of their studies, they lack the transferability into a forty-year career.

The ability to communicate well is an essential skill for engineers, but it is often not highly valued by students, and in particular first year students. In order to demonstrate the relevance of communication skills, and to encourage Engineer rather than Student behaviours, the communications skill are embedded in a technical context. This is done in the unit Engineering Foundations: Principles & Communications (EFPC).

## **Project Overview of EFPC**

The project is divided into three stages: Design, Tendering and Construction & Testing. Throughout each of these stages the students are expected to act as professional engineers.

In the first week of semester, the student engineers are required to form companies comprising five student engineers. These companies are required to register themselves with the unit coordinators, and also to establish a web presence on the unit's WebCT site. In addition to the student engineering companies, there is a web presence for two lecturer-run companies who act as the clients for the projects. These websites serve as the primary contact point for the companies throughout the course of the semester. Specifications and designs are to be made available for download from these sites; contact details for each group are made available through the websites also.

Throughout all of these stages, companies are required to keep a Company Diary, that records all of the meetings, processes and decisions of the group. The student engineers are given advice and exemplars on how to keep a high quality company diary, and are given feedback throughout the semester on how well they are maintaining the diary. The company diary is the primary instrument through which disputes between companies are resolved – when staff are called upon to intervene, it is the company diary to which they look first to seek evidence of how the dispute has arisen, and more importantly, how it could have been prevented.

### **Stage One: Product Design**

In stage one, the design stage, each company is allocated to one of two projects: a popsicle stick bridge, and a mousetrap powered car. Whilst outwardly simple items to construct, there are still many opportunities for the student engineers to demonstrate technical competence throughout the project. The exact details of the specifications vary each semester, but the overall tasks remain consistent.

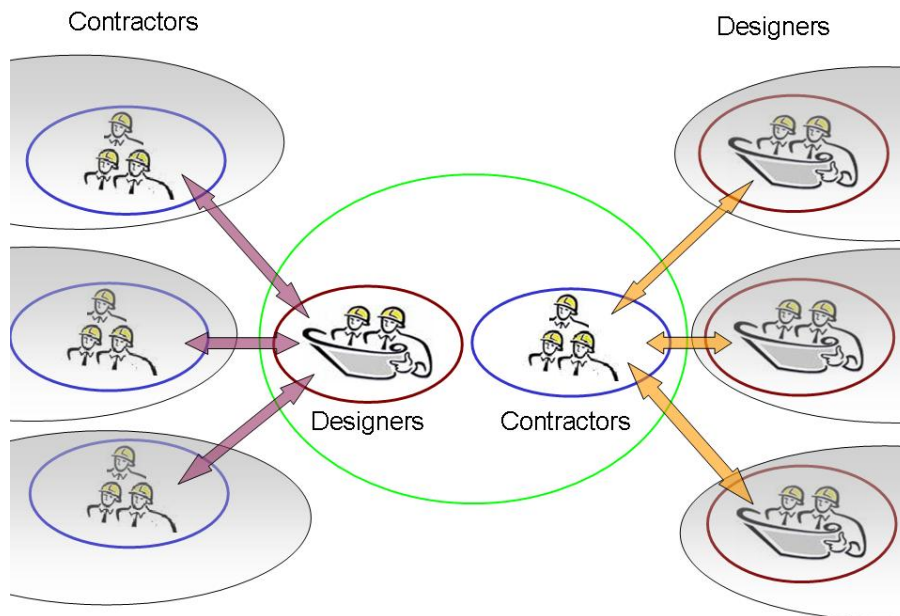
Clear specifications for each artefact are provided by the Clients through their company websites within the WebCT environment. The bridge has minimum dimensions, a maximum weight, and performance criteria with regard to the loads it must carry. The vehicle has maximum dimensions, as well as performance criteria with regard to the distance it must travel, and the speeds at which it travels. These specifications are interlinked, so that compliant vehicles should be able to travel over compliance bridges without difficulty.

The student engineers have four weeks in which to design either the vehicle or the bridge. They are encouraged to clarify with the clients on any grey areas in the specification; otherwise they are encouraged to make and document any necessary assumptions for their design process to proceed. By the end of these four weeks, each company is required to have a design for their artefact, and to have made this design available via their company website. Companies are required to produce:

- Specifications for their product
- Drawings of their product
- A certification that it meets the needs of the client
- Failure predictions for their product
- Tender Evaluation Criteria
- End-of-lifespan Disposal plan for their product

## Stage Two - Tendering

The second stage of the project is the tendering stage. In this stage, each company is allocated three other companies who must tender to build their design, and in turn, allocated three companies to which they must tender. These allocations are arranged such that each company designs one of the two artefacts and tenders to build the other. Each company assigns three of its student engineers to work as contractors, developing the three tenders to be submitted, and two student engineers to work as designers, liaising with the three other companies that are tendering to their design (Figure 1).



**Figure 1 : Designer / Contractor Interactions**

The critical challenge in this stage is for the student engineers to adapt to the perspective of the client, rather than as the producer of artefacts. The company that designs the bridge does not build it – rather, they must work with three companies tendering to build it to ensure that the bridge will be built.

Often changes to the designs are required. This is actively encouraged – it is representative of engineering practice – but it raises a communication challenge for the companies. All companies must tender on the same design specification; changes that are asked for by one tenderer must be communicated to the other companies that are tendering. Stage two has two deadlines, a week apart. The first is for the submission of the tenders; the second is for the evaluation of the tenders to be returned. At the conclusion of stage two, each company has ranked their three tenders in order of preference. Lecturing staff then allocate the companies to each other for the construction phase.

## Stage 3: Construction & Testing

Once the tenders have been allocated, the student engineers are given four weeks to construct their vehicles and bridges in accordance with the tenders they submitted to the designs they were given. The three designated contractors are responsible for the construction of their tender; the two designated designers are responsible for overseeing the company that is building their design.

The cross-section through which the vehicles must pass is matched to the minimum cross-section which the bridges must offer. To check that this has been achieved, there is cross-testing between the bridges and vehicles. Bridges and vehicles are randomly paired, and the student engineers are given three attempts to have their vehicle successfully cross the bridge.

The vehicles are then tested separately for speed and distance, and the bridges tested for their ability to carry static and rolling loads. These performances are then compared to the predictions made by the companies in stage one.

## **Learning Overview of EFPC**

The most immediately obvious observation of the overall process is that it does not run smoothly. Very few of the final artefacts are completed without some kind of bumps along the way. These bumps provide the greatest opportunity for the directly-relevant learning that we seek, for it is in these problems that they are exposed to engineering-related challenges specific to their future workplaces. The problems fall into five broad categories, which align well with the key learning outcomes of the unit:

- Unfamiliarity with teamwork
- Unfamiliarity with the role of a client
- Lack of Audience Awareness
- Inability to anticipate problems
- Inability to look beyond own direct responsibilities

### **Unfamiliarity with teamwork**

Most of the student engineers are unfamiliar with the skills required to work in a high-performance team. Many have completed group work at high school; however this group work often involves inequitable distribution of workload. In particular, first year student engineers lack the conflict resolution skills to address problems in the functioning of their team as they arise.

### **Unfamiliarity with the role of a client**

Very few of our student engineers have had any experience with the role of the client. Most of their prior experiences have been in the specification to prototype phases of the product lifecycle – they are given a task, and expected to complete it. The project has many different aspects that require the student engineers to move outside of this narrow role. Initial design, evaluation of tenders, supervision of contractors and so on all require the student engineers to work in a role other than simply implementing the instructions of others – they are expected to take initiative for themselves, and this unfamiliar role causes problems for many.

### **Lack of awareness of others' perspectives**

It is clear from reviewing inter-company communications that very few of the student engineers consider the perspective of the reader when they communicate with their colleagues. Company diaries include entries such as “we discussed the joints”, rather than documenting the decisions and outcomes that were made. There is also some considerable difficulty in communicating technical information – again a legacy of not having prior exposure to the context.

There are also difficulties with tone and expression – some of our student engineers do not make the transition from the text-message shorthand they use with their friends to the more formal tone that is appropriate for interactions with clients.

### **Inability to anticipate problems**

There are a number of setbacks that occur each and every semester as the students fail to anticipate potential problems. Glue takes time to dry; dimensions are not tolerated on drawings; team members are not available when they said they would be. That these same problems occur every semester suggests that they can be anticipated; however each semester brings a new cohort, who have not previously encountered these kinds of problems. More importantly, they also come with a limited history of projects where these kind of problems have occurred – in short, they are not used to anticipating unanticipated problems.

## Inability to look beyond own direct responsibilities

One of the biggest sources of frustrations for the student engineers is their enforced reliance upon other student engineers. Within their own team they have four colleagues that they depend upon; outside of their team they have another company building their design, and a third company overseeing their own construction. The student engineers are usually most willing to accept responsibility for their own work; they struggle to realise that they must also accept responsibility for the work of others.

Ultimately, the purpose of this project is to expose the student engineers to the engineering workplace, and to the processes and procedures that are involved therein. Many of the problems that arise throughout the project are because of the significant differences between this workplace and the students' prior experiences – this process, and the roles they must adopt within it, are completely alien to many of them, and takes them well outside their comfort zone.

Taking students outside of their comfort zone is a potential concern in the increasingly customer-satisfaction-oriented paradigm of student evaluation, it is necessary to illustrate to the student engineers key aspects of the engineering workplace. Most of our student engineers embrace the process – they want to be engineers, and they are willing to accept that they must change, and experience new things to do so. Some of our students, however, resent the discomfort, which is reflected in our evaluations.

## Evaluation of EFPC

The success of the unit has been measured using a number of different tools. The unit performs well on the University's standard teaching evaluation tools, with strong (80%) levels of agreement with items such as "I am motivated to achieve the learning outcomes in this unit" and "The learning experiences in this unit help me to achieve the learning outcomes". More illustrative of the nature of students' engagement with the unit is the open-ended feedback they provide to these surveys, and the comments that the students make in their reflective portfolios throughout the semester.

Responses tend to fit into one of two general categories: Positive feedback about the way in which the Engineering aspects of the course are emphasised, and negative feedback about the way in which the Student aspects of the course are not supported.

For students willing to leave their comfort zone, and engage as student engineers, their EFPC experience is largely positive:

*"I feel that this unit has helped me greatly towards being a practicing engineer, by teaching me how to apply my technical knowledge, how engineering is structured, and above all, how to communicate."*

*"The purpose of this unit was to change the student's mindset into thinking and working more like an engineer, this involved being capable of working with others, being able to write reflectively as well as in a standard which engineers are expected to."*

*"I have a better understanding of engineering because of this unit"*

It is clear that these students value the significant change from their prior learning experiences, and the introduction to a more authentic representation of engineering practice. This is the dominant perception, but it is by no means universal.

Considerable effort is spent to make it explicit to the students that they were expected to behave as student engineers, rather than as students. Despite this, some of the cohort either did not understand this message, or understood it and chose to ignore it. For this reason there were complaints about the unit:

*"I think it can be unfair as you are relying on other groups which can affect your own mark"*

*"I think teams functioned better when they were randomly chosen"*

*“Far too much involved in this unit”*

These are legitimate criticisms of the unit; they are also authentic elements of a professional engineering workplace. As Engineers, our graduates need to deal with clients not communicating, team members underperforming, and the consequences of not directly managing risks for which you are not directly responsible. We could certainly address these issues and improve the students' responses on evaluation surveys; however to do so would be to undermine the authenticity of the unit, and would be doing the student engineers a disservice in the long run.

The staff involved in teaching this unit also feel that it is achieving its outcomes. Whereas the previous incarnation of the Engineering Communication unit suffered from low morale amongst the teaching staff, this approach has seen a much clearer direction from the teaching staff. The integration of the communication skills into the technical context ensures that all of the staff involved in the unit are aware of all aspects of the project, rather than simply their own corner of the syllabus. This promotes a sense of a single teaching team, rather than an “us and them” mentality, which further supports the principle that the communications cannot be separated from the engineering.

## Conclusion

To an extent, the unit has been too successful. The intention is to expose the students to an authentic engineering task, and to the principles and procedures involved in completing this task. Many of these principles are completely alien to the students, lying outside of their prior knowledge, and this takes many of the cohort outside of their comfort zone. Some aspects of the unit that were essential to the authenticity of the class were in fact perceived as problems to be eliminated, rather than as learning opportunities to be engaged with.

The intention behind this unit was to create an authentic engineering experience, where we could treat our cohort as student engineers, rather than engineering students. It is clear from our feedback that we have been successful in doing this; it is also clear, however, that not all of our cohort realise that it is a success. Regardless of whether they realise it or not, it has worked.

The teaching of the professional skills has been integrated with the technical content, and the student engineers do not make the distinction between the technical and professional skills that they are developing. By treating them as engineers from day one, we have in fact helped their transition to becoming engineers.

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