# Student conceptions of civil engineering in an Engineering I course

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## Introduction

This paper is based on a project which emerged from a desire to evaluate the effectiveness of a redesigned Engineering 1 course in civil engineering. The objective of the redesigned course was to align it with the course objectives, where the course objectives can be described in terms of introducing students to the discourse of engineering, or to what it means to *think like an engineer* in the context of what civil engineers *do*.

The background to being or becoming an engineer lies in studies of graduate attributes or competencies. This body of literature focuses on the need to develop core knowledge and skills for success as an engineer. In the mid to late 1990's the focus was predominantly concerned with deficiencies in graduate engineers in terms of complementary skills such as teamwork, communications and business skills (e.g. Deans, 1999). There is a shift towards acknowledgement of the primacy of the ability to apply theoretical knowledge to real industrial applications (Royal Academy of Engineers, 2007) or as Ferguson (2006) warns, a danger of losing the basic analytical skills in the push for employment ready graduates.

The response to these concerns includes the introduction of project based courses (e.g. Lilliesköld and Östlund, 2008). Bailie (1998) showed that the most common approach to addressing the changing needs of engineering education at first year level was to introduce a new subject, usually an 'introduction to engineering' or 'professional engineering', with "an attempt to link the various parts in the course in the context of how to think like an engineer" (p.456). Our course is very typical of such a project based course.

## The course

The course is structured around six projects, each representing different specialisations within the civil engineering profession, intended to introduce the profession. These span water supply and management, informal settlement upgrades, construction, water treatment, transportation engineering, and an engineering materials and structures project. Within each project there are a number of teaching and learning activities intended to build academic and professional skills. Figure 1 represents a part of the course structure diagrammatically.

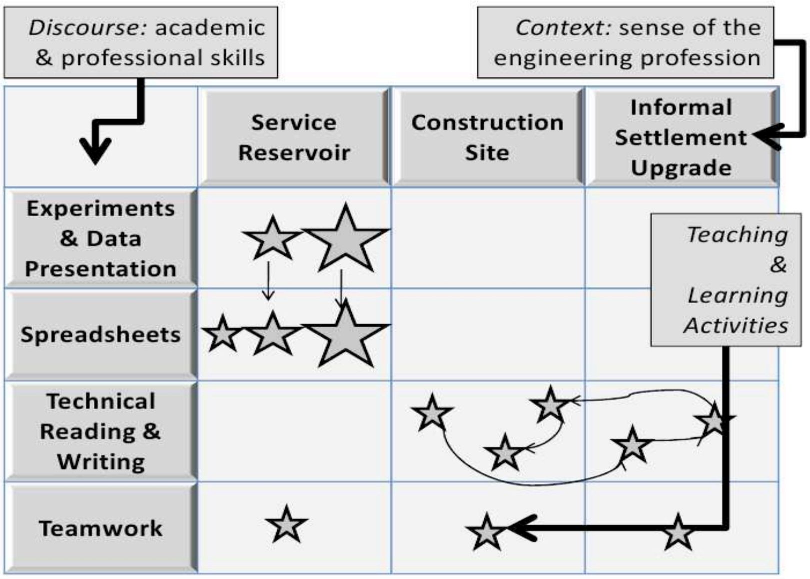


Figure 1: Partial Course Structure

By way of example of a project, the construction site project requires each team of students to negotiate access and visit a construction site periodically over a four month period. Each student is then required to individually write a substantial technical report on any aspect of construction they select. However, prior to visiting the sites there is a team project in which the team is presented with a concept related to structures or construction. The team is required to research the topic in structured library visits, produce one page reference text and a small scale model to illustrate the concept. Each student in the team then has an opportunity to teach the topic to a small group of students in the class.

Through the structured activities students are introduced to sourcing information in the library; technical reading; referencing; writing in a technical genre; and communicating technical concepts to a small group of peers. In addition each student learns about a number of concepts related to structures and construction as an orientation to their site visits.

Skills are typically not isolated to a single project, but build together through multiple projects. For example, in preparation for writing the major technical report, structure and coherence in paragraphs is introduced in the informal settlement upgrade project. The basics of experimentation, with a focus on measurements and data presentation, alongside spreadsheet functionality and design are introduced through three activities within the service reservoir project. Students are expected to use these skills in subsequent projects.

**Fluency in an Engineering Discourse**

Through their engagement on the course we hope that our students will recognise civil engineering as encompassing a broad range of specialisations, certainly beyond only designing and building structures. In fact we are hoping to get them to value the centrality of people in civil engineering and perhaps value the notion of civil engineering as science in the service of communities.

Our second objective is to develop the generic skills needed for success as a student and a professional. These include: problem solving; computing; experimentation; teamwork; communication, both formal and interpersonal; and time & study management. To a large extent the generic skills identified as important are those articulated as Exit Level Outcomes (ELO) by ECSA (Engineering Council of South Africa, 2004) as a requirement for programme accreditation within the Washington Accord.

But possibly more importantly we hope our students can contextualise the activities as ways of *doing* engineering and *being* an engineer. Not only do we want them to learn to solve problems, but to take on ways of approaching problems, ways of representing information (data and writing) such that they will be recognised by others as legitimate engineers or engineering students. The philosophy underpinning the course is founded very strongly on Gee's (2005) ideas around Discourse, where Discourse (with a capital D) is seen as encompassing not only words, but also ways of being, doing and valuing. Central to this is the crux of being recognised by others as being in the Discourse, and therefore the course tries to make explicit what counts as legitimate ways of doing engineering and being an engineer.

However it can be assumed that students experience the course in a multiplicity of ways, some more aligned with the course intentions than others. The focus of this study is on how students conceive of becoming an engineer through their experiences in the Engineering I course, and what meaning do they attach to these experiences.

**Theoretical framework**

Phenomenography is the research approach which was adopted for this study. One of the aims of phenomenographic research is to "study how people experience a given phenomenon" (Orgill, 2007, p. 133) i.e. a second order research approach. A defining feature of phenomenography is that the researcher is interested in the variety of experiences across a group rather than richness of individual experiences. For example, in phenomenography learning is viewed as "a change in the ways in which one is capable of experiencing some aspect of the world" (Booth, 1997, p.135). When using it as a lens for educational settings the focus is on the understanding of the content in these settings as a consequence of engaging with various learning activities (Booth, 1997).

Since the objective of phenomenography is to capture variation, purposive sampling is required. We selected 6 participants based on a comparison of their performance in the course and on other first year subjects. Two participants where high achievers on all courses, two were passing this course reasonable well, but had failed other courses and two students had left the civil engineering programme, having struggled to meet minimum academic performance requirements. We also had representation across race and gender.

An additional interesting variation picked up from the interviews related to their reasons for choosing to study civil engineering. One participant admitted to knowing nothing about civil engineering before entering the programme. Two were still more interested in a different career, but followed civil engineering for different reasons, in the first case in accordance with family pressure, and in the second as a result of being rejected for the first choice. Three had chosen civil engineering because of their strength in maths and science coupled with a desire to 'make a contribution to society' in some way. Of these three two had a clear affinity for engineering and had made a conscious choice between alternatives, while the third seemed to be struggling with his motivation.

While we do not claim to have exhausted the variation that we are looking for, the variation in background knowledge, academic performance and affinity for the profession suggest good potential for variation in experiences. In addition, because of the very diverse range of projects within the course we would expect students to experience variation within their individual experiences.

**Discussion**

The data revealed four distinct categories of variation in the way that the students experienced the course activities building in both complexity and abstraction. These categories are named in the horizontal axis in the table below. The distinctive features between the categories are most clearly seen in the four structural themes shown vertically in table 1.

**Table 1: Categories of description and structural themes**

| | **Civil Engineering is conceived of as** | | | |
|---|---|---|---|---|
| **Category / Theme** | **Collection of activities** | **Range of specialisations** | **Multidisciplinary Problem Solving** | **Independent Problem Solving** |
| **What counts as civil engineering knowledge** | No engagement with what constitutes engineering knowledge | Literal interpretation. Activities constitute engineering knowledge. | Use of scientific understanding (disciplinary knowledge) to model physical things. | Engineering disciplinary knowledge is multidisciplinary. |
| **Approaches to civil engineering problems** | Dependence: Problem, solution and process defined by the lecturer, no role for decisions. | Dependent on specialisation, decisions are made external to engineers. | Compromise: No clear process for comparison and evaluation of choice. | Independence: Adapt generic approaches, and evaluate choices to justify decisions. |
| **Role of People** | Limited to engagement with people on the course, rather than external stakeholders. | Some specialisations are seen as more people intensive than others. | Scientific considerations are seen in conflict with people. | Civil engineers work in the service of societal needs. |
| **Drawing on course activities to make sense of engineering practice** | Disconnection between project activities and engineering practice. | A literal understanding of what engineers do. The activity fully represents practice. | Recognition of the scientific complexity behind apparently simple technologies. | Projects seen as simplifications of complex systems. |

**Collection of activities**

A response typical of the first category is:

> S1: I learned about how to treat water - checking and all that –
> *CS: And what was it about that one that helped you understand what it is to be an engineer?*

> Um - I don’t know - I just enjoyed them.

However there were also indications that certain projects lent themselves more to this category of experience:

> S4: I thought it was a really pointless module, cos we didn’t understand, we had to use some formulas. I’m sure 90% of the people didn’t even understand what those formulas are for, or why we’re using them. Normally you have to understand before the process that goes into deriving the formulas but I didn’t understand what are those, cos when it came to my report, I just started chucking in numbers and submitted. Luckily I passed it.

**Range of specialisations**

By comparison, in the second category students begin to link the activities into a broader view of the engineering profession. They see multiple opportunities for specialisation in the future:

> S2: ... it showed like where we can go with Civil Engineering, like I had no idea that there was so much water flow dynamics and so on, in Civil Engineering, I thought it was mostly structures, as a lot of people do assume, it’s mostly structures, and I had no idea water treatment was part of Civil Engineering, it never occurred to me, and I think it was a really nice way of like showing all the different ways, things you can go into, and what you’ll be able to do when you’ve got your degree. It was enough to give you a very good idea of what each section of Civil Engineering is like.

There is a strong link with the application of scientific knowledge within these specialisations:

> S6: it added quite a bit but what it added was on more on a specialist field - it gave me an appreciation of what goes into the little things in life that we take for granted and how much work and thinking engineers actually put into those.

However there is a tendency to make a very literal translation between the course activities and the engineering profession, a sense that they are mimicking exactly what engineers do.

> S5: like this water treatment thing it really was what civil engineers do. The transport thing also - it was just like giving us a glimpse of what we are to expect in future.... - to say *OK I know how to do water treatment.*

**Multidisciplinary problem solving**

The third category starts to pull the specialisations together, with recognition of the multidisciplinarity of many problems.

> S2: it obviously needs to stand, and the, the structure needs to hold, that is the key, but it needs to, the impact it has is how people are going to see it and how people are going to interact with your structure, and that is going to be what reflects the success of your structure.

But a sense of how to balance conflicting requirements is missing. In fact satisfying the needs of people is often seen to compromise “good science”:

> S6: that water is clean but - it is clean but it smells - they have to add some chemical to help it smell nice but as engineers they know that it is clean, it doesn't have to smell nice, it can look green but it is clean but because people have perceptions and expectations you have to now suddenly *alter and undo your potential good work to satisfy people*.

There is a danger here that students compromise their own science when they view the profession from this perspective, or it gives them a sense that they can avoid rigorous scientific reasoning in their solutions because it will be compromised anyway.

> S6: I would say there is a focus on maths on that side but from what I saw the maths that we need is really too much in the sense that there maybe you will maybe have to integrate - you won't have

> things such as triple integrals - you'll just have to integrate maybe the volume of a certain room so that you get - you can install the correct air-conditioning or whatever it maybe not triple integrals.

**Independent problem solving**

In the final category the focus is also on problem solving, but the main distinction with the previous category lies in a more rational basis for dealing with conflicting requirements, possibly to look beyond the immediately apparent and find out more.

> S3: I always thought engineering or maths or science - it is either right or it is wrong - this project - it was all about making compromises. What could possibly be best - there are always pros and cons to every decision you make with regards to upgrading informal settlements which method, which approach you take - some people are always going to lose out ... I guess that was good to know that it is not all black and white an*d sometimes you have to do research to find out what the best compromise*

There is also a more abstract view of the link between the course activities and the engineering profession, an acknowledgement that this is not what engineers do, but rather a representation:

> S3 I was also frustrated there were two experiments that we had to do. The one was with the tin can and the other one was with the water drum and that felt very simplified and crude but I learned from that and you go back to something simple to understand and you develop a model from that - you don't have to go and develop a model on a dam because you won't know where to start - it is just too big.

**Implications for the course**

In terms of meeting the first course objective, that of exposing students to a range of specialisations within civil engineering, the introduction of coherent projects certainly allowed for most students to recognise multiple fields in the profession. Even in the first category there was a sense of the different activities that they engaged in. For many this provided a sense that they have options for specialisation in the future. However it was clear that some projects lent themselves more obviously to higher order conceptions of civil engineering than others, and illustrates the importance of the explicit location and background of the project context.

By articulating qualitatively different ways in which students conceive of engineering, we saw a clear distinction based on how students deal with conflicting requirements in problem solving. For some students the need to meet ‘soft’ or social requirements resulted in the potential to compromise science. We are left with a concern that in certain contexts, some students may avoid rigorous scientific reasoning in their solutions because they conceive of it as being compromised anyway.

Generic skills form an integral part of the course and students referred to activities they recognised encouraged development of skills such as team work, forms of communication, experimentation, thinking critically and time management. It was encouraging to see that students referred not only to teamwork, but also to interpersonal skills and respect. However in some cases skills were conceived as separate and concrete entities, whereas the intention of the course is that these skills become a part of a person as we develop. In a course where skills development is so central to the course objectives, and where they play a foreground role in the teaching and learning activities, more attention needs to be given to how they become embodied.

**Phenomenography as a tool for evaluating a course**

We found the strength of the phenomenographic analysis to lie in the rigour required to identify qualitatively different descriptions between categories of variation. In addition, the methodology forces recognition of the contextual and temporal nature of individual experiences, allowing for variation in each individual’s experience. This provided useful insight into strengths and weaknesses in different projects, often in terms of how explicitly the projects relate to students’ conceptions of engineering. On the other hand, separating the data from the rich narrative of individual students led to a loss of the affective layer of data. It was interesting to see how their affinity for their conceptions of engineering practice and their own success in the other science courses frame their experience of this course. We found it difficult to capture this layer using phenomenology.

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