

**Science and Mathematics Education Centre**

**The Effectiveness of Project-Based Learning In  
Structural Engineering**

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## **Abstract**

The dominant pedagogy for engineering education still remains chalk and talk despite the large body of education research that demonstrates its ineffectiveness. Traditional approaches to structural engineering education place a heavy emphasis on lecture-based delivery of the theories of structural analysis and the behaviour of common construction materials. Design projects are given varying emphasis at different institutions, but are frequently left to the final year of the course. Assessment weighting often heavily favours examinations over project work. In recent years, the engineering profession and the bodies responsible for accrediting engineering programs have called for change in assessment and teaching practices.

This study proposed that the use of design projects in structural engineering is an effective method of learning that models industrial practice. Projects enable students to understand the synthesis of structural analysis, material behaviour and availability, constructability and economic reality that occurs in the professional practice of structural engineering. To examine the effectiveness of project-based learning in structural engineering a case study was undertaken in a third year undergraduate course of a civil engineering program in South Australia.

This thesis first provides some background to structural engineering and current practice in structural engineering education. Project-based learning as applied to engineering is also examined. The case study design and data collection are then discussed. The study was developed around a conceptual framework for educational evaluation that differentiates between the intended, implemented, perceived and achieved curriculum. The intended curriculum, defined as the original vision underlying a curriculum, was developed through a literature review that considered the requirements of industry and engineering accreditation bodies. The degree to which the intended curriculum was successfully implemented in the course was evaluated through video-tapes of lessons, journal records and interviews. The actual learning experiences as perceived or experienced by the students, was evaluated through student journals, interviews and two questionnaires, one of which was also administered to a senior structural engineering industry group to enable a comparison between the student and industry groups' perceptions of the importance of certain skills in the structural engineering profession. The achieved curriculum, defined as the resulting learning outcomes of the students, was also examined. The thesis concludes with a discussion of the findings of the study as well as their significance and limitations and then considers the possible extensions of project-based learning to other areas of engineering and some of the issues that will need to be addressed for this to occur.

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# Chapter 1: Introduction

## **The Research Problem**

Traditional approaches to structural engineering education place a heavy emphasis on lecture-based delivery of the theories of structural analysis and the behaviour of common construction materials. Design projects are given varying emphasis at different institutions, but are frequently left to the final year of the program. Assessment weighting often heavily favours examinations over project work.

This study proposes that the use of design projects in structural engineering is an effective method of learning that models industrial practice. Projects enable students to understand the synthesis of structural analysis, material behaviour and availability, constructability and economic reality that occurs in the professional practice of structural engineering. Hence such projects should be given central emphasis in structural engineering courses.

This research first determines the needs of the structural engineering industry with regard to skills required of graduate engineers and then examines how project-based learning in structural engineering can be implemented to enable students to acquire these skills. A case study of the effectiveness of project-based learning in structural engineering has been undertaken in the third year of an undergraduate civil engineering program in South Australia. The perceptions of students on the value of the design projects as a learning experience have been investigated. Finally, an evaluation of learning outcomes achieved through the use of project-based learning in structural engineering has been made.

## **The Research Questions**

The objective of this research program was to evaluate the effectiveness of design projects as a means of learning structural engineering. Specifically the study has investigated the following research questions:

1. What do students of structural engineering need to learn in order to be able to design/construct engineering structures when they enter professional practice?
2. How can these learning requirements be implemented through a project-based curriculum?

3. What do engineering students perceive as the relevance of project-based learning to the professional practice of structural engineering?
4. How effectively do engineering students achieve the intended learning outcomes using a project-based approach?

## **Background of Structural Engineering Education**

Structural Engineering is one of four main specialist areas of Civil Engineering (the others are geotechnical, water, and transportation engineering). The fundamental core of structural engineering is design. To structural engineers, design is what they do when they develop the schemes for construction of a bridge or building, deciding how it will support the loads to which it will be subjected, whilst remaining safe and serviceable for its occupants, yet also retaining the external appearance required by the architect. Structural engineering is also the products that come from these decisions and which are used to communicate the design to those who will actually build the structure, usually drawings, backed up by calculations and experience.

Until the late 18<sup>th</sup> century, the design and construction of structures such as buildings and bridges was as much an art as a science, and those in charge of the process were master tradespeople. Experience of what had worked in the past and how it was done were the most important components of the knowledge base required. With the developments in understanding of physics, mathematics and science in general that accompanied the industrial revolution, structural engineering started to become a profession requiring more scientific knowledge, but still relying greatly on practical experience and knowledge of construction methods. Although engineering education gradually became a part of universities over the 19<sup>th</sup> century, it was still a largely practice-based program, with design classes as a significant part of the curriculum until the mid-twentieth century. Since that time, mathematical theory and structural analysis have largely displaced design from the curriculum. Along with that trend has been the replacement of studio-type design classes by lecture-based delivery of scientific content. These trends are increasingly being questioned by industry practitioners and professional accreditation bodies. Further discussion of these issues is included in Chapter 2. However, some of the concerns about the lack of change in engineering education methods over the last 40 years have been summarized by Felder, Woods, Stice and Rugarcia (2000) as follows:

The literature in general education, technical education and educational psychology is replete with methods that have been shown to facilitate learning more effectively than the traditional single-discipline lecturing approach. Unfortunately, these developments have so far had relatively little impact on mainstream engineering education. Although their content has changed in some ways and the students use calculators and computers instead of slide rules, many engineering classes in 1999 are taught in exactly the same way that engineering classes in 1959 were taught. (p. 26)

## **Project-based Learning and Problem-based Learning**

Problem-based learning was introduced in the area of medical education in the 1960's and has been suggested as a solution to the problems in engineering education raised by Felder et al. above. Other authors suggest that project-based learning is more appropriate for engineering. The review of literature in Chapter 3 will define what is meant by both problem-based and project-based learning, why they are used, and how and where they have been implemented to date, focusing particularly on engineering examples. The major objection raised against the use of either problem- or project-based learning in engineering, as compared with medicine, is that engineering requires knowledge of core areas such as mathematics and physics, and that the nature of engineering knowledge is hierarchical and sequential. Consequently, undergraduate engineering degrees tend to spend the early years on core knowledge courses taught in discrete units, and then continue to teach discrete areas of engineering specializations as separate courses, rather than integrated wholes. However, it is possible to argue that despite the differences in undergraduate degree structures that have, to date, prevented problem-based or project-based learning from being introduced across engineering degrees when compared with medicine, the differences between the roles of practitioners in each profession is not so marked. For example, a comparison of the process of structural engineering design undertaken by a professional engineer with the diagnosis and treatment of an illness by a medical practitioner, shown in Table 1.1, is analogous.



**Table 1.1 – A comparison of the process of medicine and structural engineering design**

<b>Medicine</b>	<b>Structural Design</b>
What are the patient's presenting symptoms and signs? Obtain further information from the patient. Examine the patient for further information. What further investigations are required to confirm likely hypothesis?	What does the structure need to do? What are the design criteria? Examine the environmental conditions, functional requirements, loads etc.
What is the most likely diagnosis based on the evidence available?	Define the structure form and function, dimensions, location
What are the possible treatments? Explore alternatives	Evaluate alternative layouts, alternative construction materials and methods, alternative structural analysis systems
Select the most suitable treatment and determine its administration (required dose etc.)	Select most suitable materials, method of construction and structural analysis system.
Administer and monitor treatment and return to earlier steps if not successful	Conduct the analysis and detailed design, draw it and cost it. If uneconomic return to earlier steps.
Patient recovers, or illness managed with on-going treatment, (or patient dies)	Construct the structure and maintain it as necessary.

Given these similarities in practice, if it is not considered generally feasible to introduce problem-based or project-based learning across a complete engineering degree, it should still be possible to introduce some of the philosophies behind it into individual courses or course streams.

## **Theoretical Framework**

The theoretical framework that best encapsulates the beliefs about knowledge and learning which underlie both problem-based and project-based learning is that of constructivism. Constructivism maintains that knowledge is not received passively but is built up by the cognizing subject (Treagust, Duit & Fraser, 1996, p. 4) and that meaningful learning is possible only when the learner relates new material substantively to his or her already existing cognitive knowledge base (Hativa, 2000, p. 56). The modification of the learner's existing knowledge base to incorporate the new material will occur only if it is considered to be interconnected to that knowledge base, and to provide more acceptable conceptual explanations than the previously held understandings. Constructivist learning is an active process in which teaching is integral to support learning by listening to and understanding students' knowledge concepts, adopting teaching approaches that promote conceptual change, and assessing learning in a manner that supports these changes.

The constructivist view of teaching and learning focusses not on teacher performance and tools, but on students' learning. Teaching strategies are not thought of in terms of teaching methods but in the aims for student learning in and the extent to which a particular strategy achieves the principles of effective instruction within a particular context (Ramsden, 1992, p. 150). The constructivist definition of curriculum has been stated as "the set of learning experiences which enable the learners to develop their understanding" (Driver & Oldham, 1986, p. 106). This view may mean that content must be reduced. As expressed by Starr and Krajcik (1990, p. 989), "this deeper understanding can only occur by "doing less", in other words by stressing the importance of understanding a few important concepts well, as opposed to covering many concepts."

A substantial examination of four research perspectives of learning and instruction in science education was carried out by Eylon and Linn (1988). The perspectives considered were concept learning, developmental, differential and problem solving. Eylon and Linn also concluded that content in the science curriculum may need to be reduced, and that "systematic, sustained coverage of a few science topics can simultaneously address students' incomplete or inaccurate notions and can promote development of problem-solving skills" (p. 290).

In its original development, the theory of constructivism focussed on conceptual change as a result of changes occurring within the thinking of the individual student. More recently the belief that the individual's learning has been over-emphasised and that social issues in knowledge construction processes have been neglected has led to the proposal of a modified constructivist theory, that of social constructivism. In this context, students' learning is considerably enhanced by interaction with peers about specific conceptual challenges. Terms such as situated cognition, authentic learning situations and cognitive apprenticeship have been developed in relation to social constructivism (Duit & Treagust, 1998). Savery and Duffy (1998) have proposed three philosophical characteristics of social constructivism (p. 55), namely, understanding is in our interactions with the environment; cognitive conflict or puzzlement is the stimulus for learning and determines the organization and nature of what is learnt; and knowledge evolves through social negotiation and through the evaluation of the viability of individual understandings.

From these propositions, Savery and Duffy have developed a set of instructional principles deriving from social constructivism as follows:

5. Anchor all learning activities to a larger task or problem.
6. Support the learner in developing ownership for the overall problem or task.

7. Design an authentic task.
8. Design the task and the learning environment to reflect the complexity of the environment they should be able to function in at the end of the learning.
9. Give the learner ownership of the process used to develop a solution.
10. Design the learning environment to support and challenge the learners' thinking.
11. Encourage testing ideas against alternative views and alternative contexts.
12. Provide opportunity for and support reflection on both the content learnt and the process. (pp. 57-59)

A wide variety of learning environments may be developed that reflect these instructional principles derived from social constructivism. However, problem- and project-based learning environments particularly capture these principles through the use of authentic problems or projects, relevance to professional practice and the use of students' own knowledge bases (conceptions) as the starting point for learning. The use of teams to undertake projects enables cooperation/collaboration, social interaction and negotiation of understandings. Through problem- and project-based learning, students gain ownership of the problem and direction of the learning as well as opportunities to reflect on their own work.

## **Curriculum Framework**

The framework for the curriculum of the course that was used in this research is one that was developed by Keeves (1972 and 1995), and modified or developed further by Treagust (1987), Cuban (1992) and Van Den Akker (1998). The curriculum has been defined concisely by Taba (1962) as a "plan for learning" and elaborated further by Walker (1990, p. 5) as "The content and purpose of an educational program together with their organization." Rosier and Keeves (1991) suggested that the (science) curriculum could be viewed in terms of "three sequential stages, which related to three groups of agents involved in science education, namely the curriculum planners, the classroom teachers and the students. These stages are (1) the intended curriculum, (2) the implemented curriculum, and (3) the achieved curriculum." (p. 5) An additional stage, also related to the students, and included by Treagust (1987), is the perceived curriculum. These four aspects that were used in evaluating the curriculum's effectiveness in this study are summarised in Table 1.2.

**Table 1.2 – The four stages of curriculum used for evaluation**

<b>Stage</b>	<b>Description</b>
Intended curriculum	The original vision underlying a curriculum, possibly in the form of a national curriculum document or accreditation criteria. Within a particular course, this may be presented in the form of a course or subject document.
Implemented curriculum	The actual instructional process as implemented.
Perceived curriculum	The actual learning experiences as perceived or experienced by the students
Achieved curriculum	The resulting learning outcomes of the students

The *intended* curriculum may also be labelled as the recommended, adopted, official, formal, explicit or ideal curriculum (Cuban, 1992, p. 222; Van Den Akker, 1998, p. 421). In the case of K-12 education, this is usually specified by a national or state education authority. It may consist of a detailed specification of both what is to be taught and the process by which it should be taught, or it may be a statement of general guidelines. In the case of engineering the *intended* curriculum could most closely be modelled as the accreditation guidelines for professional engineering programs within each country. These guidelines generally provide a broad framework for content of the engineering programs as a whole, but the Australian and UK guidelines provide no specific advice with regard to structural engineering. The Accreditation Board for Engineering and Technology (ABET, 1999) from the USA does give some specific guidance for Civil Engineering programs (of which structural engineering is a part). However, the intended curricula for individual courses within a university engineering program are usually specified and approved by the engineering department itself and are often published in a course catalogue and/or web pages.

The *implemented* curriculum, also termed the operational, taught, implicit or delivered curriculum (Cuban, 1992, p. 222; Van Den Akker, 1998, p. 422), consists of the formal and informal teaching actually delivered in a classroom or lecture room. The interpretation of the intended curriculum developed by each individual teacher or faculty member may be documented by means of course outlines, handouts, practical activities, project outlines and assessment tasks, amongst others. In the context of structural engineering, the implemented curriculum will be the interpretation and emphasis that an individual lecturer chooses to place on the broad topics specified in the published course documentation. It should be noted that in university environments, specified topics in an intended curriculum might quite easily be omitted or replaced by individual lecturers to some degree, possibly to suit their individual expertise, particularly in later year specialist courses. This organisation is generally accepted provided that all the prerequisite topics for subsequent courses are taught.

The *perceived* curriculum was included by Treagust (1987) to describe the curriculum as actually experienced by the students (termed “experiential” curriculum by Van Den Akker, 1998, p. 422). It can be gauged, for example, by students’ responses to learning environment questionnaires and/or to interview questions. This stage in the curriculum process may be overlooked if we only consider the final stage of *achieved* curriculum (also referred to as “learned” or “attained”, Cuban, 1992, p. 222; Van Den Akker, 1998, p. 422). Rosier & Keeves (1991) defines the achieved curriculum as:

... the extent to which individual students have internalized the experiences that were planned and organized for them. The achieved curriculum indicates how much scientific knowledge the students have learnt, how much competence they have gained in inquiry skills, and what attitudinal and value changes they have made. This final stage in the curriculum sequence is measured by means of science tests and other instruments completed by the students in the study. (p. 7)

The difference between perceived and achieved curricula is that the latter is interpreted by the teacher/lecturer from more formal assessments, such as tests, and may not always give the complete picture. It is quite possible for students to achieve reasonable marks on a test, which might indicate that they have achieved the learning outcomes that the teacher/lecturer believes he or she has implemented. However, the students’ perceptions of what they have actually learnt may be quite different. They may indicate that they have learnt enough to pass the tests, but not actually developed their conceptual understanding in the course. The opposite may also be true. Students may indicate, through interview, that they have developed good conceptual understanding of the implemented curriculum, but they may not have demonstrated formally that they have achieved this, if they had a bad day on the test, or if they routinely do badly in formal assessments.

## **Research Methodology**

A case study approach was used for this research. In a recent review of “What is a case study?” Bassey (1999) offered no less than 15 varying definitions by different researchers of what constitutes a case study and its interpretation as an educational research tool. This study has adopted the following definition by Anderson (1998), which has been developed from Merriam (1988) and Yin (1994):

A case study is a holistic research method that uses multiple sources of evidence to analyze or evaluate a specific phenomenon or instance. Most case study research is interpretive and seeks to bring to life a case. It often, but not exclusively, occurs in a natural setting and it may employ qualitative and/or quantitative methods and measures. (p. 152)

A case study method was the most appropriate technique for this present study because the situation being researched was a natural setting with a multitude of variables. It was not possible to separate and control particular variables in the proposed routine classroom setting, as required for a scientific experiment type approach. In addition, the author had dual roles in the study as both researcher and teacher hence these influences were an unavoidable component of the situation being studied (Wong, 1995). The case studied was bounded or specific in that it was restricted to the particular cohort of students and their study of a particular course. Multiple sources of data and data collection methods were employed and triangulation (Mathison, 1988) was used to interpret and develop generalisations from the study.

## The Case Study

The researched case was a structural engineering course, Building for People N, at the University of South Australia. The course, taught in Semester 1 of the third year of a four-year undergraduate civil engineering program, in 2001, is the first exposure of the students to structural engineering after their basic Mechanics, Engineering Science and Materials type courses. The class size in the study was 21 students. Full details of the case study methodology adopted are discussed in Chapter 4. Terminology for university courses and other factors varies from one institution to another and from one country to another, so the definitions in Table 1.3 are those that have been adopted throughout this study (except where quoting from another author).

**Table 1.3 – Definition of terms used in the study**

<b>Term</b>	<b>Description</b>
Program	The complete program of study required to obtain an undergraduate degree, usually of four years duration for engineering degrees in Australia and the United States
Course	A component unit of study within the undergraduate program. Other terms that may be used include subject or unit. Typically a student may be enrolled in 4 courses per semester.
Faculty	The academic staff (member or team) responsible for teaching a course (the more usual Australian term would be lecturer)

## Significance of the Study

The present study is significant for several reasons. One of the most important reasons relates to the nature of the current literature in engineering education. Whilst the learned discussion on education within an engineering context continues to grow through journals and conferences, the concern encapsulated by Felder et al. (2000) is that:

The literature is full of articles by professors who have tried new methods and written about the results. However, the validity of a method must remain suspect if the only evidence on its behalf is one person's testimony that "I tried this and liked it and so did the students." (p. 27)

As most of the articles are written by engineering faculty with no formal training in education, there is little attempt to relate any of the work undertaken to educational theory in order to examine its effectiveness. For example, an analysis of articles in the *Journal of Engineering Education* over the period 1993 to 1997 showed that only 13.4% of the articles used any educational theory (Wankat, 1999). This point was also articulated by science educators Clough and Kauffman (1999) in an article on improving engineering education where they stated:

While acknowledging the value of anecdotal evidence and individual studies, we advocate treating teaching as an ongoing scholarly practice where existing and new research is organized into a robust framework that produces a total effect greater than the sum of the independent parts. (p. 527)

The present study uses the educational theory of constructivism and a curriculum framework developed for educational evaluation to examine the effectiveness of project-based learning in one branch of engineering education. The research is designed to show the way for engineering faculty to examine their programs from a more rigorous educational theoretical background.

It is anticipated that the study will show whether or not project-based learning is an effective method for structural engineering education. If the approach is effective, there are several possible significant developments. Firstly, a change of current teaching practice is possible and improved learning outcomes may be achieved even through a limited implementation of projects within individual courses. Secondly, if the method is effective in structural engineering, then a wider application is possible in other areas of engineering. Thirdly, if the study demonstrates that students gain a better conceptualisation of what practice is about through undertaking project-based learning, then those students will be able to function immediately in the professional workplace once they have completed their undergraduate

studies. The last point should have significant benefits for employers of graduate engineers in particular and for the engineering profession as a whole.

## **Limitations of the Study**

A more detailed discussion of the validity and reliability of the study is included in Chapter 4. However, one aspect that needs to be discussed at the outset, as part of the development of the internal validity of the study, is the background and opinions of the researcher with regard to the topic of the study, so that the researcher's perspective is made clear to the reader.

### **Researcher's background**

The researcher completed her undergraduate degree with Honours in civil engineering at the University of Adelaide in 1981. The civil engineering program at that time relied primarily on lecture-based instruction (as was typical of engineering at all Australian universities in that era) with 90% of assessment based on final examinations in most courses. However, the program did incorporate design projects in some courses, particularly in structural engineering, even though the assessment weighting given to these projects was negligible. In addition, the program incorporated a major research project and major class design project in the final year. Hence, the researcher was exposed to the use of design projects within her own undergraduate training. Twenty years later, almost the only aspects of her undergraduate education that the researcher can recall well are the topics and nature of each of the five projects undertaken in her course and the lecturers who taught them.

Although the researcher achieved excellent results in the lecture- and examination-based program of her undergraduate training, she felt distinctly lacking in real knowledge when she entered her first graduate position. (Of course, the lack of confidence could also have been related to being one of only 0.6% of the engineering workforce that was female at the time, and the only female amongst her department of over 200 engineers, but that will be viewed as a separate issue). The major concern she felt was that she had been taught a lot of theory but had little idea of how to apply it in practice. This knowledge was gradually accumulated as the researcher worked on various projects under the supervision of more experienced engineers. In due course, the researcher became responsible for training newly graduated engineers employed at her workplace and the same pattern was observed – the graduates might have done well at university, but they didn't really know where to start on practical projects.



Some engineers would argue that such on-the-job training is the way it should be, and that the role of universities is to provide the theoretical knowledge, and of industry to provide the practical training. However, during the researcher's time in industry, the nature of the engineering workforce changed radically. For example, the large electricity generation and supply organisation at which she commenced work after graduation employed over 2000 engineers and 25000 employees in total at the time. Within ten years, the organisation no longer existed, it had been broken up and privatised, and each of the small replacement organisations employed almost no engineers, but used consulting engineers instead. This pattern of the breaking up of the large utility organisations that had previously employed and trained many graduate engineers was repeated throughout the country and through all sectors of the public and semi-public services. In the engineering workforce in Australia from the 1990's and onwards, graduate engineers have no longer had the luxury of gradually learning on the job with the guidance of senior engineers. All engineers, including new graduates, are predominantly employed in the private sector and graduate engineers are now expected to 'hit the ground running' and learn very quickly on the job. If they do not succeed, then they do not survive long in the industry, due to the financial pressures of the private sector.

The researcher had no contact with the university environment for 15 years after graduation while she worked in industry. In 1996, she was given the unusual opportunity of a lecturer's position at the University of South Australia on the basis of her industry experience, despite having no higher degree or research background, because the university was seeking to redress the gender imbalance in its engineering faculty profile (i.e. they had no female faculty members). From the outset of her university employment, due to her industry background, the researcher was asked to teach all of the existing structural design project components within the civil engineering program at the university as well as the final year Design Project course. In addition, the lecture components of some of the structural engineering courses were also the responsibility of the researcher.

The researcher's interest in the topic of this study has stemmed from several observations that she has made during her teaching experiences and her reading in engineering education over the last five years. These observations include the following:

- Different students prefer different styles of learning, but almost no students learn successfully by attending lectures alone.
- No matter how entertaining a lecturer might be, lectures can be boring for both lecturer and students.

- No matter how well a concept is presumed to have been taught during a lecture, the majority of students will at best only partly understand it until they have been asked to apply it, either through an open-ended tutorial problem or a design project.
- The progressive use of projects of increasing complexity through a program enables students to re-visit and reinforce conceptual understanding so that by graduation they at least understand the fundamental concepts well, even if they may not have grasped all of the complex concepts yet.
- Some students who strive for and demonstrate conceptual understanding during a course, as demonstrated by the questions they ask and discussions they have with the lecturer, are unable to demonstrate this understanding through examinations. Nevertheless, the majority of these students go on to be quickly employed and successful engineers in practice. Conversely some students who do very well in examinations struggle in practice when they enter industry.
- Projects that mirror industrial reality are well regarded and motivating for both students and staff, and success in those projects is well regarded by industries that employ graduate engineers.
- The study of educational theory and methods, even if focussed on engineering, is not considered to be valid research by most engineering faculty, and consequently the outcomes are generally ignored by faculty members, even when aware of them.

In summary, the researcher's observations and experience have convinced her that there are better ways of teaching and learning than the traditional lecture-centric methods of engineering. In contrast, her personal experience as an engineer has been with project-based learning in structural engineering. However, her own evidence and the majority of the evidence she has read regarding the effectiveness of project-based learning has been anecdotal and not grounded in educational theory. Therefore, the researcher decided to provide evidence for herself as well as for other engineering faculty that project-based learning is an effective way to teach structural engineering, by undertaking a study with a sound educational theoretical background, within an engineering framework.

Hence the researcher's bias with regard to this study rests in her beliefs about three issues. Firstly, changes in the nature of the engineering industry and engineering employment over the last 20 years require changes in the way that engineering is taught. Secondly, other teaching methods than project-based learning may also improve learning outcomes in

engineering students, but project-based learning is the method most familiar to the author and the one that she believes most closely mirrors industrial practice. Thirdly, the researcher's observations of the outcomes of project-based learning indicate that it *seems* to be an effective means of teaching structural engineering but she would like more convincing evidence to satisfy herself, and to be able to use to convince other engineering faculty of its value if demonstrated by the study.

## **Summary**

This chapter has summarised the nature of the research problem and the specific research questions to be addressed in the study. The background of the subject area of the study (structural engineering), the teaching methodology of project-based learning and the theoretical framework of constructivism being used in the study have been discussed. The case study research methodology has been outlined, as well as the curriculum framework that has been used to evaluate the effectiveness of the curriculum utilised in the study. Finally, the significance of the study to the field of engineering education and the limitations of the study with regard to the researcher's background and initial perceptions have been examined. Subsequent chapters examine the existing literature that relates to the study, detail the methodology used and evaluate and discuss the results and outcomes of the research.

# Chapter 2: Issues in Engineering Education

## Introduction

In order to understand the context of this particular study on project-based learning in structural engineering, it is first necessary to develop an understanding of the background of engineering education in general, and structural engineering education in particular. The following review of literature considers the history and the development of engineering education to the present time, with a particular focus on structural engineering education, and develops a framework of critical issues relevant to the study. Accreditation criteria for engineering programs in Australia, the United Kingdom and the United States are considered and compared. The needs of industry with regard to the skills and abilities required of engineering graduates in general, and structural engineering graduates in particular, are examined. In particular, the professional registration criteria for structural engineers in Australia and the United Kingdom are considered in detail, due to their usefulness in answering the first research question of the study - What do students of structural engineering need to learn in order to be able to design/construct engineering structures when they enter professional practice?

## Issues in Engineering Education

### History of engineering education

The development of engineering as a profession from its previous status as a master trade originated in Europe as a consequence of the industrial revolution in the late 18<sup>th</sup> and early 19<sup>th</sup> centuries. This was accompanied in the latter part of the 19<sup>th</sup> century by the development of engineering science and its inclusion in programs of engineering education, particularly in Britain under the influence of W.J.M. Rankine (Johnston, Fourikis, Dietrich, & Gostelow, 1989). The addition of engineering science training to the practical skills signified the birth of engineering as a profession. Another characteristic of engineering education that has existed until very recently is the notion of being value-free; in other words, the development and use of technology has been promoted through engineering education without requiring students to consider the possible social, environmental and economic impacts of that technology.

The USA experience of engineering education has been summarised by Prados (1998), Lang, Cruise, McVey and McMasters (1999) and Lahoud (1990). The US engineering curriculum and faculty that existed from the beginning of engineering education in the early 19<sup>th</sup> century until approximately 1950, after the end of World War II, was strongly practical, much more so than today. Prados (1998) recalls that at the time when he commenced engineering studies in 1947, engineering was highly practical, “with little application of mathematics beyond elementary calculus and strong emphasis on design according to codes and other well-defined methods outlined in the standard handbooks. Most engineering faculty had significant industrial experience and/or close ties with industry” (p. 1). But with the demands on the profession that came from the rapid technological advances of the war, Prados argues that there was a need for a much stronger foundation in mathematics as well as in basic sciences and engineering sciences in the post-war era.

Lahoud (1990) describes the particular situation with regard to structural engineering and asserts that faculty before 1950 were often actively involved in structural engineering practice and hence incorporated the practical aspects of the design profession in their teaching. These aspects included design office practice, fabrication issues, on-site inspections, use of design industry codes and detailing issues. However, Lahoud also points out that the practice of structural engineering at that time was more straightforward than today, with the involvement of the engineer in all aspects from design to fabrication to erection. There was much less litigation and confrontation between the owner, engineer and contractor. The graduate engineer of the time also was provided with considerable on-the-job training and commenced their professional life with routine tasks.

From 1950, the federal government in the USA decided to support much of the nation’s fundamental technological research through universities, which led to “the emergence of the engineering faculty career path dedicated to sustained basic research activities” (Lahoud, 1990, p. 110). Research skills and experience became the dominant knowledge base of the faculty responsible for undergraduate education. The practice-oriented focus of programs changed to a mathematical, engineering science focus, which has remained the focus for the vast majority of US programs since that time. Consequently, many current faculty, who are the products of these programs from the 60’s, no longer have the practical experience that was previously passed on to students.

Another factor of importance in the early 1960’s was the emergence of the computer as a powerful analysis tool. Since it was clear that computer analysis and methods would become a cornerstone of engineering practice, something had to be removed from or reduced in the curriculum to make room for computing. According to Lahoud (1990), the usual choices for

omission were those topics that faculty felt could be acquired on the job, such as drawing, surveying, design and detailing.

Although this description is predominantly that of the US experience, as with many areas of professional practice, Australia has similar developments to some extent. Whilst the faculty background and experience in Australia are not yet exclusively research-based, this is the tendency for current appointments. A perusal of position advertisements in the *Australian Higher Education Review* on any given Wednesday will attest to the fact that this is increasingly the experience being sought by universities.

### **The nature of the modern engineering profession**

A paradigm change is the situation being faced by today's engineers according to Newport and Elms (1997):

Early engineers believed in, and worked in a society that believed in, technology for its own sake. The paradigm was that the engineer was an agent of technological change, carrying little or no responsibility for outcomes. Today, engineers are faced with a significantly different paradigm. They are expected to bring a combination of technology, economics, social consciousness and environmental awareness to engineering works to ensure the "most possible good" is derived for both present and future communities. Engineers have always had to deal with technological change, but now there is a different change, a change of role. The job they do has broadened significantly in scope, and engineering education must change in response. (p. 325)

This paradigm change means that different skills and attributes are required of the modern engineer than of their counterparts prior to, say, 1980. As expressed by Beaufait (1993):

To practice engineering in the world of the 21<sup>st</sup> century, I strongly believe that our students must not only have a solid foundation in the liberal arts, but must also have an awareness of how our society functions, the problems it faces and how it deals with these issues. Our society needs engineers to move out from the computer and into public service. It is also becoming more important for our students to learn something about management. Not only must the engineer of tomorrow be a team member but a team leader. This aspect of an engineering student's education is more important than learning the latest analytical technique that the faculty member has just published. (p. 1640)

The modern engineering profession deals constantly with uncertainty, with incomplete data and competing (often conflicting) demands from clients, governments, environmental groups and the general public (Stevens & Wilkins, 1993, p. 7). Engineering requires skills in human relations as well as technical competence.

Whilst trying to incorporate more human skills into their knowledge base and professional practice, today's engineers must also cope with continual technological and organisational change in the workplace. In addition, they must cope with the commercial realities of industrial practice in the modern world, as well as the legal consequences of every professional decision they make. Summarising this legal reality in the context of structural engineering, Lahoud (1990) states:

The practice of structural engineering has also changed. The United States has been called the most litigious nation in the history of the world. This fact is evident in the field of structural engineering. Designers must now strive to limit their exposure. The overriding design objective is often to minimize risk of legal controversy. Structural designers struggle to adjust their practice to this environment. Innovative designs must be considered with caution or avoided to minimize risks. (p. 112)

Lahoud goes on to say that modern engineering graduates now enter their first job without many of the skills they require, including any perception of the legal and regulatory environment in which they must practice. Lahoud states that the greatest strength of recent graduates is in the area of computer analysis, but that this may represent only 20 to 30 percent of the design effort required for a project. The remainder of the effort involves preparation of drawings, details, specifications, and performing quality control and he believes that recent graduates have no experience of this in their education that will assist them in these tasks.

Whilst the Australian engineering profession is by no means free of the legal ramifications of practice in the United States, there is a more concerted attempt to use risk management and partnering between owners, engineers and contractors in this country, to produce win-win outcomes for all parties involved in projects (including the general public) and to avoid the massive legal actions of the United States.

### **Recent reviews of engineering education**

The changing role, responsibilities and knowledge base required of modern engineers has led the profession to review the education currently offered to engineering students in several

countries, including Germany, Canada, USA and Australia. The German Verein Deutscher Ingenieure (VDI) has recommended that the engineering curriculum should focus more on fundamental principles and less on in-depth specialisation in a chosen application (cited in Institution of Engineers, Australia (IE Aust), 1996a, p. 87). A similar recommendation also has been made by the Canadian Academy of Engineering (Slemon, 1993, cited in IE Aust, 1996a, p. 89) which advocates broader, less specialised, more integrated undergraduate programs with increased emphasis on design and social context. The Canadians also recommend increased interaction between engineering professors and practitioners in the profession as well as one-year professional Master's programs.

A report entitled *Engineering education for a changing world* summarised a review of engineering education in the USA conducted by the American Society for Engineering Education and the Engineering Deans Council (1994). The summary recommendation was that "Engineering education programs must be *relevant, attractive and connected.*" (p. 3, on-line version) The report suggested that there would be a continued need for all engineers to be educated with sound fundamentals, but that a variety of models could exist for individual universities. Some might focus on a broad education aiming to prepare students for technological decision-making and policy-setting as well as for non-engineering professions. Where institutions focussed on preparation for professional engineering practice, this would normally be achieved with a Master's level program after the undergraduate degree. A further model that may be adopted in institutions with a research tradition would be a degree that focussed on research and preparation for research and teaching careers. Further recommendations related to ensuring that faculty reward systems support the institutional goals and education model and to reshaping curricula to incorporate multi-disciplinary perspectives, societal context, teamwork and communication skills, and ethics. Industry links were advocated both in providing lifelong learning through collaboration as well as exchanges of personnel between faculty and industry. Finally, research and resource sharing between consortia of engineering colleges, including education resources, was recommended.

In Australia, an extensive review of engineering education, entitled *Changing the culture: Engineering education into the future* (IE Aust, 1996a), was conducted jointly by the Institution of Engineers, Australia, the Australian Council of Engineering Deans and the Education Committee of the Academy of Technological Sciences and Engineering. The review established six task forces to consider each of six foci, namely, students, industry, the profession, educational programs, institutional policies and the community. Each task force consulted widely with the relevant stakeholders and reported separately to the review (IE Aust, 1996b).



In contrast to the reviews of other countries discussed previously, the Australian review recommended that the four-year full-time program should remain the minimum requirement for professional accreditation. Whilst it did recommend that the education must be broad in terms of multi-disciplinary, societal, economic and environmental contexts, the recommendation remained that graduates from such a program must possess in-depth technical competence in at least one engineering discipline, as is currently the case in Australia. This is primarily due to the nature of the profession in a small economy such as Australia, where engineering companies must be able to work in a broad range of areas to be viable, and where the only niche or specialist companies tend to be individual or very small consultancies. Consequently, engineering graduates from Australian universities have traditionally undertaken training in a broad discipline range. For example, civil engineers trained in Australia usually take more than one course in each of the major specialisations of civil engineering, that is geotechnical, structural, transportation and water engineering, and may enter any of these professional areas on graduation. In other countries such as the USA, it is unlikely that a graduate would enter a professional design practice in any of these areas without having undertaken some additional coursework beyond the undergraduate qualification. This is partly due to the higher level of mathematics and science required of Australian students on entering programs than that of the typical USA high school graduate (see for example University of Missouri-Rolla, 2001).

In 1995-6, the Institution of Engineers, Australia conducted a review of engineering education (IE Aust, 1996a) that resulted in a list of 14 recommendations, which relate to both the detail of engineering programs and their administration, research, school and industrial links. Those relevant to this study include:

- Engineers must receive a broader education and be drawn from a wider range of backgrounds.
- Engineering courses must have clearly stated goals and outcomes and equip graduates for lifelong learning.
- Professional accreditation systems must encourage innovation in course content and delivery.
- The four-year full-time course equivalent must remain the minimum requirement, but diversity must be encouraged.
- Staff profiles must balance teaching, research, professional practice and community skills.

- There must be greater collaboration between the engineering schools and industry.

### **What does industry want from engineering graduates?**

In recent years, studies have been conducted in many countries to determine the technical and personal abilities required of engineers by today's industry. These studies have informed the reviews of engineering education discussed above and have had a major influence on the revision of national accreditation criteria for engineering programs in countries such as the USA (Accreditation Board for Engineering and Technology (ABET), 1999), UK (Standards and Routes to Registration (SARTOR), 2000) and Australia (IE Aust, 1999), as is discussed below.

Henshaw (1991) conducted a study of Australian employers to determine the attributes that they would seek when employing engineering graduates. As part of this process, he analysed employment advertisements for graduate professional engineers and found that the most dominant attribute and skill requirements were computer literacy (in 28% of all advertisements), communication skills (24%), ability to work in a team (24%), interpersonal skills (16%) and self-motivation (16%). In fact, almost all of the attributes and skills mentioned in the advertisements "were human rather than technical skills" (p. 200). Henshaw also conducted questionnaire surveys of employers, practising engineers, recent graduates and academic staff members (i.e. faculty). All groups rated communication skills as highly desirable. Employers rated problem-solving ability highly, while practising engineers and recent graduates emphasised commercial and industrial skills and engineering design skills, respectively. The most disturbing trend was that "Apart from communication skills, academics have little in common with the other parties in rating the most desirable attributes; the gap (or chasm) between what is taught and what is deemed to be required doesn't appear to narrow with time." (p. 204)

Several surveys of industry expectations of new engineers have been carried out in the United States. Lang et al. (1999) reported the results of a survey of 15 aerospace and defence companies (with 420 responses received from engineers and engineering managers in these companies) where the respondents were asked about the perceived importance of 172 attributes related to the 11 ABET Program Outcomes and Assessment categories (see below). The aim of the survey was to set up a database that could be used by curriculum designers to consider the requirements of industry in developing an undergraduate curriculum to satisfy the revised ABET 2000 accreditation criteria. Some of the abilities that received highest importance ratings included:

- Engineering courses with applications.
- Ability to structure, solve and report on solutions in the engineering specialty.
- Demonstrated ability in data analysis and interpretation.
- Team experience as a team member.
- Ability to formulate a range of alternative problem solutions.
- Demonstrated understanding of the importance of the code of ethics in engineering.
- Interpersonal skills (verbal, non-verbal and written) that maintain high professional quality, convey appropriate respect for individuals, groups, teams and develop a productive working environment.
- Understanding that skill training is employee's responsibility and part of life long learning.
- Computer literacy in analysis and design tools in engineering specialty. (pp. 48-51)

A study focussing on the civil engineering industry, reported by Back and Sanders (1998), involved structured interviews with 42 industry participants from 18 different companies representing owners, designers, constructors and subcontractors. All participants agreed that communication skills (both written and verbal) were extremely important, but that new graduates generally not only lacked these abilities, they also failed to understand and appreciate their importance. Team skills, also seen as vital, included skills to negotiate, resolve conflict, handle stress, share in task accomplishment and build positive working relationships with others in a group setting. The industry representatives reported that more than 90% of all work is conducted as a team effort. Technical skills were regarded as essential to successful engineering practice and, as a whole, the industry was generally accepting of the technical skills of new graduates. Business skills were seen as useful, but not as important as communication, team and technical skills. Industry opinion varied widely about whether universities should focus primarily on a theoretical education with few specifics about practical applications, or alternatively, should teach specific skills to permit immediate effectiveness in the workplace. The general consensus was that universities should concentrate on fundamental theory, but that this should be supplemented by using projects to illustrate how the principles are practically applied.

The findings of a survey of students, employers, general public and faculty conducted by Arizona State University and reported by Evans, Beakley, Crouch and Yamaguchi (1993)

were very similar to those of both Lang et al. and Back and Sanders. Leading industry figures also have provided their individual views of what is needed from today's engineering graduates. Jerry Junkins, chairman and CEO of Texas Instruments, has said, "Most engineering jobs involve design and practice, not theory and research" (quoted in Dutson, Todd, Magleby, & Sorensen, 1997, p. 18). Kent Black (1994), executive vice-president of Rockwell International Corporation, discussed the global competition faced by all industry sectors, but particularly the electronics industry. He believes that today's engineers in his industry still need fundamental physics and chemistry knowledge, but that they also need an understanding of customer needs and environmental issues, effective time management and communication skills, a team approach throughout their work, a thorough understanding of current design tools and a sense of the total business equation – profit and loss and balance sheet issues.

An interesting variation on these reports was the study conducted by Newport and Elms (1997) on effective engineers. The study first conducted open-ended interviews with 16 senior engineers from a range of organisations and disciplines to develop a list of effective engineer qualities. After eliminating synonyms, overlapping items and those mentioned only once from the original list of 200 qualities, a final list of 68 qualities resulted (refer Newport & Elms, pp. 327-8 for the complete list). Subsequently, questionnaires were given to senior engineers, one for each engineer they supervised, and they were asked to rate each engineer on the extent to which they exhibited the effective engineer qualities, as well as their overall effectiveness. A total of 77 engineer-supervisor sets were used in the final data. A correlation between the engineers rated as effective and the qualities they possessed was then conducted, and produced some very interesting outcomes. Thirty-four of the 68 qualities correlated significantly with effectiveness, loosely categorised into three groups:

1. Mental agility: Lateral thinking, creativity, judgement, flexibility, practicality, ability to work under pressure, economic, environmental, political and community awareness.
2. Enterprise: Initiative, resourcefulness, motivation, ambition, confidence, energy, willingness to take risks.
3. Interpersonal capabilities: Perception, sociability, leadership, team-working, negotiation, interpersonal skills, people orientation, humour, respect for other opinions, decisiveness, extroversion.

One of the most interesting findings was the qualities that did not correlate well with effectiveness:

Academic achievement showed virtually no correlation with engineering effectiveness. The same was true of many of the qualities traditionally associated with engineers such as technical competence, numerical ability, logical thinking ability, methodicity, self-discipline, industry and integrity.

It could therefore be said that while it is nearly impossible to obtain an engineering degree without being technically competent, numerically skilled, etc., the possession of these qualities does not guarantee success or effectiveness. They are necessary but not sufficient. However, it is also true that a minimum level of attainment is all that is required. Outstanding academic achievement does not necessarily lead to greater effectiveness. (p. 330)

While these findings are probably glaringly obvious to those engineers who have spent any length of time practising in the engineering profession in private industry, or to those responsible for hiring graduate engineers, they are probably a rude shock to many academics.

By contrast to the previous studies, Todd, Sorensen and Magleby (1993) reported results of a survey of engineering employers that summarised the weaknesses they perceived in recent engineering graduates, rather than the abilities that they would like. The weaknesses they reported included technical arrogance, lack of design capability or creativity, lack of appreciation for considering alternatives, lack of appreciation for variation, all wanting to be analysts, poor perception and narrow view of engineering and related disciplines, weak communication skills and little skill or experience in working in teams.

In summarising all of these studies, some key factors seem to emerge. Today's engineering graduates need to have strong communication and teamwork skills, but they often do not have these skills. They need to have a broader perspective of the issues that concern their profession such as social, environmental and economic issues, but they often do not have this perspective. Finally, they are graduating with good knowledge of fundamental engineering science and computer literacy, but they often do not know how to apply that in practice.

### **Accreditation of university/college engineering courses**

Becoming a fully qualified professional engineer is a three-stage process. The first stage is graduation from an accredited engineering course; the second is a period of practical experience and the third is professional registration either through examination or some other application process supervised by the professional engineering bodies in each country. This section concentrates on the first of these stages.

Accreditation of engineering programs is carried out by different bodies in each country, but the overall requirements are similar. Accreditation generally is moving away from the earlier quantitative or prescriptive models. Until recently programs were generally accredited if they could provide satisfactory answers to the following type of questions – how many students does the program have?, how many faculty?, how many support staff?, what is the area of your teaching and laboratory space?, how much money do you spend on equipment each year?, etc. The programs also needed to comply with some specified course requirements and durations, e.g., one semester of Physics, three semesters of Mathematics, as well as demonstrating that certain topics were included in the courses.

The more recent move in Australia, UK and USA at least has been to an outcomes-based assessment. The new approach shifts emphasis away from “what is being taught” to “what is being learned” (Koehn 1999b, p. 163). Engineering programs are now required to demonstrate that their graduates are achieving a set of specified learning outcomes, and the means of demonstrating this is left to each university to decide and implement. This will usually include demonstrating that the quality management systems are in place for components such as course development, teaching and learning, staff development, etc. that will ensure that these outcomes are met, as well as some follow-up surveying of recent graduates. There are also some requirements in each country for increased management education, design education and industry relevance of programs. As these revised accreditation procedures are only now being introduced in each country, it is unclear at this stage how successful they will be.

### Accreditation in the USA

In the United States, accreditation of all undergraduate engineering programs at 311 universities (Rosenbaum, 1996, p. 27) is carried out by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology, Inc. (ABET). From the 2001-02 college year onwards, all programs will be evaluated under a new set of criteria known as Engineering Criteria 2000 (ABET, 1999). An extract from this document including the particular requirements for Civil Engineering programs has been included as Appendix A1. The fundamental abilities and outcomes required of graduates from all engineering programs are summarised in Table 2.1. These abilities and outcomes are quite different from the previous conventional criteria and have provoked considerable discussion. One of the major concerns is whether these criteria will be fully enforced, and whether engineering programs that are unable to meet them will actually lose accreditation or just receive a stern warning to upgrade the program. The new process requires self-evaluation and continuous improvement in the engineering schools, a process now almost universal in

modern industry, but virtually foreign to the academic culture. A major challenge for ABET will be to “train enough visiting team members and chairs to apply accreditation criteria that are vastly different from those of the past.” (Prados, 1998, p. 5).

**Table 2.1 – Program outcomes for graduates from ABET accredited engineering programs (from ABET, 1999, p. 32)**

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<b>Engineering graduate outcome</b>
1. An ability to apply knowledge of mathematics, science, and engineering
2. An ability to design and conduct experiments, as well as to analyze and interpret data
3. An ability to design a system, component, or process to meet desired needs
4. An ability to function on multi-disciplinary teams
5. An ability to identify, formulate, and solve engineering problems
6. An understanding of professional and ethical responsibility
7. An ability to communicate effectively
8. The broad education necessary to understand the impact of engineering solutions in a global and societal context
9. A recognition of the need for, and an ability to engage in life-long learning
10. A knowledge of contemporary issues
11. An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

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ABET (1999) gives some specific guidance for Civil Engineering programs (of which structural engineering is a part) for the curriculum:

The program must demonstrate that graduates have: proficiency in mathematics through differential equations; probability and statistics; calculus-based physics; and general chemistry; proficiency in a minimum of four (4) recognized major civil engineering areas; the ability to conduct laboratory experiments and to critically analyze and interpret data in more than one of the recognized major civil engineering areas; the ability to perform civil engineering design by means of design experiences integrated throughout the professional component of the curriculum; an understanding of professional practice issues such as: procurement of work; bidding versus quality based selection processes; how the design professionals and the construction professions interact to construct a project; the importance of professional licensure and continuing education; and/or other professional practice issues. (p. 39)

Similarly for the expertise of the faculty:

The program must demonstrate that faculty teaching courses that are primarily design in content are qualified to teach the subject matter by virtue of professional licensure, or by education and design experience. The program must demonstrate that it is not critically dependent on one individual. (p. 39)

Koehn (1999a; 1999b) conducted a survey of students and alumni in civil engineering at Lamar University to gauge support for these specific civil engineering criteria. He found that overall 66.7% of the subject areas in the civil engineering program criteria were rated highly in the survey, which he interpreted as strong support for the criteria. However, some of the criteria relating to professional issues such as procurement of work, bidding versus quality based selection, interaction of design and construction professionals, and importance of continuing education were rated of lower importance and possibly should not be stressed to the same degree in the program (Koehn, 1999b, p. 165). Interestingly, the criteria rated equal or most highly by all groups in the survey were that “design experiences (be) integrated throughout the curriculum” and that a “major design experience or course” be included. (Koehn, 1999a, p. 11)

#### Accreditation in the UK

The Engineering Council is the national registration authority for professional engineers in the United Kingdom (Engineering Council, 2000). Engineering degrees are accredited by one of the 16 Institutions licensed by the Council; for example, the Institution of Civil Engineers accredits civil engineering undergraduate degree programs. The regulations produced by the Council for assessment of these programs and professional registration are known as SARTOR (Standards and Routes to Registration) (SARTOR, 2000). These regulations also have been extensively overhauled recently, with the current version issued in late 1997 for discussion, and implemented in the 1999-2000 academic year. The educational base for undergraduate degrees in these regulations are specified in Table 2.2. Specific guidance on the requirements of civil engineering programs is not given in SARTOR or by the Institution of Civil Engineers.



**Table 2.2 – Requirements for accredited undergraduate engineering degrees in the United Kingdom (from SARTOR, 2000, Part 2, Sec 4.1.1)**

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<b>Requirements for an accredited engineering degree course</b>
12. Provide a foundation for a wide range of subsequent study and develop a positive attitude towards lifelong learning.
13. Motivate students towards the practice of engineering and stimulate their learning.
14. Set the engineering science within the context of real engineering applications.
15. Be taught in the context of design, so that design provides an integrating theme which exposes students to a proper mixture of analysis, synthesis, conceptual design and the other issues listed below.
16. Present an intellectual challenge, whilst integrating theory with current industrial practice.
17. Ensure that the social, legal, economic and political contexts within which engineers operate are understood.
18. Contribute to the personal and professional development of students in the context of the applications of engineering and the need of modern businesses for articulate, problem solving and aware graduates.

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#### Accreditation in Australia

In Australia, accreditation of engineering programs is carried out by the Institution of Engineers, Australia. Similarly to the USA and UK, the accreditation requirements also have undergone major revision recently, being released for discussion in late 1997 and fully implemented for the first time in 2001 (IE Aust, 1999). The IE Aust documents list a set of generic attributes that engineering graduates should possess, see Table 2.3, which arose directly from the Review of Engineering Education (IE Aust, 1996a). Unlike the UK or USA documents though, the Australian regulations still give some typical content requirements for engineering programs that they expect to be followed, as detailed in Table 2.4. The Australian regulations also specify that students must be exposed to professional engineering practice integrated throughout their program, and that this exposure must include “use of staff with industry experience.” (IE Aust, 1999, p. 6)

**Table 2.3 – Attributes required for graduates from accredited undergraduate engineering degrees in Australia (from IE Aust, 1999, p. 5)**

<b>Required graduate abilities</b>
1. Ability to apply knowledge of basic science and engineering fundamentals.
2. Ability to communicate effectively, not only with engineers but also with the community at large.
3. In-depth technical competence in at least one engineering discipline.
4. Ability to undertake problem identification, formulation and solution.
5. Ability to utilise a systems approach to design and operational performance.
6. Ability to function effectively as an individual and in multi-disciplinary and multi-cultural teams, with the capacity to be a leader or manager as well as an effective team member.
7. Understanding of the social, cultural, global and environmental responsibilities of the professional engineer, and the need for sustainable development.
8. Understanding of professional and ethical responsibilities and commitment to them.
9. Expectation of the need to undertake lifelong learning, and capacity to do so.
10. Contribute to the personal and professional development of students in the context of the applications of engineering and the need of modern businesses for articulate, problem solving and aware graduates.

**Table 2.4 – Typical elements required in four-year undergraduate engineering degrees in Australia (from IE Aust, 1999, p. 6)**

<b>Typical elements required in undergraduate engineering degrees</b>
11. Mathematics, science, engineering principles, skills and tools (computing, experimentation) appropriate to the discipline of study. This element should not be less than 40% of the total program content.
12. Engineering design and projects. This element should be about 20% of total program content.
13. An engineering discipline specialisation. This element should be about 20% of total program content.
14. Integrated exposure to professional engineering practice (including management and professional ethics). This element should be about 10% of total program content.
15. More of any of the above elements or other elective studies. This could be about 10% of total program content.

### **Implications for teaching and learning in engineering**

What then are the implications of: the changing nature of the modern engineering profession; the reviews of engineering education that have been conducted; the advice from industry of

what they want from engineering graduates; and the radically revised accreditation requirements for engineering programs for the teaching and learning of engineering? It seems obvious from the foregoing discussion that the profession, the industry employers and the students themselves are all calling for significant changes. What then are the major issues that need to be addressed, and what are the suggested ways to address them? The most critical issues, the literature that supports them, and the suggestions made to address them are discussed below.

#### Critical Issue No. 1

*Engineering curricula are too focussed on engineering science and technical courses without providing sufficient integration of these topics or relating them to industrial practice. Programs are content driven, rather than process driven.*

Dunn-Rankin, Bobrow, Mease and McCarthy (1998) at the University of California Irvine note that, historically, universities have taken the responsibility for rigorous theoretical and technical training in subjects that include the basic sciences and fundamentals of engineering. At the same time, industry has been responsible for training engineering graduates in specific tasks important to the company and its core competency. The problem that arises in this division of training, however, is that no one teaches students how to apply fundamental engineering principles to practical problems.

Dunn-Rankin et al, have queried their graduates after they have spent some time in industry, and found that the feature of their UC-I education that they underutilise (and even discard) is the fundamental training. They assert that the faculty contribute to this rejection of fundamentals by avoiding exercises that demonstrate how to apply what they teach to real problems.

Similarly Bordogna, Fromm and Ernst (1995) assert that universities say to their beginning engineering students:

You have studied physics, chemistry, mathematics, humanities and social sciences in high school and gained admission to our college. Now go away and study the same subjects for two more years, then we'll let you study engineering. (p. 193)

This view is echoed in Australia by Wallace (1996) who observes that most engineering courses are currently based on the development of fundamental scientific principles, which are separated into discrete content areas with engineering applications provided later in the course. Assessment is mostly related to the demonstration of technical concepts and

principles in closed-ended problems which “creates an emphasis on the technical in existing courses, to the exclusion of the human context.” (p. 202)

Professor David Elms of the University of Canterbury in New Zealand has included several of these issues in his *Myths of engineering education* (Elms, 1990). One myth is that “The fundamentals are physics, chemistry and mathematics” (p. 8). Whilst Elms agrees that these are necessary fundamentals (but the proportions required will vary according to each engineering discipline), he suggests that four new fundamentals are also required: an ability to handle ideas, an ability to communicate well, training in the systems approach, and exposure to aspects of both the natural and social environment. Other myths relate to the content driven and high workload nature of most engineering programs such that “It is necessary to expand the course to cover all necessary knowledge”, that “Cognitive content is all-important”, and that “Engineering needs a fully-packed timetable.” (p. 8)

The solutions generally proposed to overcome this first critical issue involve a fundamental redesign of the curriculum in engineering programs, although there are several difficulties that need to be considered in this process. One of these difficulties is the tunnel vision of engineering education described by Evans et al. (1993) that is a result of a top-down design of engineering curricula, which leads to a focus on course hours and syllabi “while ignoring larger issues such as how students actually learn and the continuity and overall purpose of the curriculum design problem.” (p. 204) They advocate a “bottom-up approach that first establishes curriculum purpose and emphasis (i.e., specifications) based on discussion and consensus agreements among employers of engineers, alumni, students and faculty – the customers of the educational system.” (p. 204)

Wallace (1996) suggests a similar process and that the development of generic attitudes and values should not just be implied in a curriculum then left to chance. The attitudes and values must be explicitly stated (along with technical content and skills) in program documents, course outlines and in specific teaching objectives, and must be assessed at appropriate levels. Curriculum statements should demonstrate where these skills are learnt, where they are practised and where they are assessed (p. 203).

One of the major inhibitors of this type of curriculum redevelopment is the culture of academia, which is often driven by faculty self-interests or factors external to the departments themselves. Although the engineering profession itself relies on teamwork, the engineering faculty culture (in common with most other academic faculties) remains one of individual promotion and self-interest. Many faculty members are focussed primarily on their own research interests and are reluctant to devote more than cursory effort to

redeveloping their own teaching, let alone being involved in a major curriculum revision for the entire program. There is a frequent belief that their specialty area is vital and fundamental to the program and attempts to incorporate it in other courses, teach it through a different methodology or delete it from a program, are strongly resisted. There are financial pressures from Divisions and institutions as a whole to teach programs in the most cost-effective manner, so large lecture classes as well as mathematics and sciences taught as service subjects by other departments remain the norm. Another discouragement is that when faculty are already carrying heavy workloads, there is just too much paperwork involved in making changes. When faced with writing endless documents to gain Department approval, Academic Board approval, university approval and accreditation, it is seen as easier to leave things as they have always been. Engineering program curricula are frequently then a compromise, which unfortunately means a set of separate, disconnected courses, taught by individual faculty, with possibly some coordination of course streams (e.g. the structural engineering courses), and a major design project tacked on at the end to keep industry and accreditors happy.

#### Critical Issue No. 2

*Current programs do not provide sufficient design experiences for students.*

This issue has been supported by several authors cited above but can be summed up by Nicolai (1998):

The engineering curriculum must let the student experience being an engineer by introducing problem situations which force the student to link engineering theory to real-world problems by doing some original thinking, evaluating alternate solutions, making a decision and defending it. The best way to do this is by giving the student open-ended (or design) problems since these are the only type of problems that occur in industry. (p. 10)

Whether as a legacy from the earlier, practice-based programs, or whether as the simplest way to satisfy previously token accreditation requirements in this area, most engineering programs have retained a capstone design experience. This is usually a single course taken in the final semester, final year of the engineering program that is meant to bring together all of the previously taught theory and apply it in a major design project. However, the quality of these capstone courses varies widely, depending on the commitment of the faculty and department to them, and there may be few or no other design experiences in a program. All of the revised accreditation criteria discussed earlier have maintained a design experience requirement, but the requirement has been considerably strengthened and made more

explicit. The Australian requirement of 20% of total programs to be engineering design and projects is the weakest expression of the design criteria compared with those of the UK and USA, although even 20% of total programs would still require considerably more than a single capstone course to satisfy. The USA and UK criteria specifically require that design experiences must be an *integrating theme* throughout the program. To satisfy these criteria will require major program revisions for many institutions in these countries.

### Critical Issue No. 3

*Graduates still lack communication skills and teamwork experience and programs need to incorporate more opportunities for students to develop these.*

Felder, Woods, Stice and Rugarcia (2000) state this requirement clearly:

Most engineering is done cooperatively, not individually, and technical skill is often less important than interpersonal skill in getting the job done. In survey after survey, representatives of industry place communication and teamwork at the top of their lists of desirable skills for new engineering graduates. If teamwork is such a critical part of what engineers do, surely engineering schools should provide some guidance on how to do it. (p. 33)

It is unlikely that students will acquire communication and team skills with our “traditional, passive, lecture-based learning and competitive reward structure.” (Prados, 1998, p.2) Prados points out that most educational experiences throughout school and university emphasise individual achievement and penalise teamwork (often called cheating), yet in the engineering profession, success depends on the combined efforts of all team members more than those of any individual.

There are several ways that programs could choose to implement increased communication and teamwork skills. Some feel that they have satisfied the communication skill requirement if they require students to take a liberal arts course or two. Others do incorporate specific courses on communication skills, possibly taught in cooperation with communication faculty (a good example is the course *Communication and the Profession* at the University of South Australia). Whilst the latter is certainly to be recommended, Nicolai (1998) points out that this issue can easily be satisfied by tying it to the design requirements discussed previously. If students can experience realistic design problems in all four years of the program, then since most design problems lend themselves to team effort, these should be done in small teams (three to five students) “as this will be the way they operate in industry. Team efforts are a marvellous place to develop the communication and interpersonal skills.” (p. 12)

There also should be other opportunities incorporated throughout the curriculum for students to make oral and written presentations and to work in small groups or class groups. Students should be encouraged to regard their classmates as potential work colleagues and consider questions such as “Would you like to be sharing the work load with this person?”; “What skills and strengths will that person bring to a design task, to a conference with clients, etc.?” Even the traditional laboratory report can be used as an opportunity to develop communication and team skills in both carrying out the practical work and writing up the results, or possibly presenting the results to the rest of the class. Reports should be assessed and feedback provided for the quality and clarity of the presentation and content, as well as the conceptual understanding demonstrated. Issues then arise, though, regarding individual or group assessment for such presentations.

#### Critical Issue No. 4

*Programs need to develop more awareness amongst students of the social, environmental, economic and legal issues that are part of the reality of modern engineering practice.*

The choices available to implement this requirement are similar to those available to gain communication and teamwork skills. Students should be required either to undertake courses in other areas such as law or economics, be offered specific courses in these areas tailored to engineering or, probably again the most effective and practical approach, integrate the development of this knowledge through design experiences, which is where it lies in practice.

#### Critical Issue No. 5

*Existing faculty lack practical experience, hence are not able to adequately relate theory to practice or provide design experiences. Present promotion systems reward research activities and not practical experience or teaching expertise.*

The cause of much of this problem, and the biggest difficulty to be overcome in solving it, is funding. In the USA, Prados (1998) and Rugarcia, Felder, Woods and Stice (2000) point to the reality of financial pressures on many engineering schools that mean they depend heavily on outside research funding to operate. This scenario has led to the establishment of success in research as the primary criterion for promotion and the potential for attracting research funds as the primary criterion for hiring. One of the means to change this situation might be to encourage industry to fund teaching rather than research in some instances, as they will gain from this by having better trained engineering graduates available for them to hire. This

may require some government support if research funding provides tax incentives while other types of funding do not. In the meantime, Melsa (1997) has instituted some low-cost or cost-neutral measures at Iowa State University, which should be more widely adopted. These measures include the development of professional exchange programs between industry and the university and the use of a sabbatical to gain industrial experience. In addition, these measures emphasise the importance of industrial experience on the resumé of a faculty member (p. 244). Since the new ABET criteria specifically require that faculty members teaching design must have experience or professional licensing in that area, and that the programs cannot be dependent on one individual, this will effectively force some institutions to hire faculty in this area. (ABET, 1999)

In Australia, the funding situation for many engineering programs is also critical, but not as dependent on research funds, although these certainly help. Many programs depend heavily on funds from overseas fee-paying students, but consultancy with industry is a valuable source, providing current practice exposure for faculty. The federal government is proposing a performance-based funding model, which will include among its key indicators, performance in research and in teaching and learning. This should help to reverse the present trend amongst Australian universities to hire faculty based on their research record rather than practical experience or teaching ability, in a misguided imitation of US practice.

The other issue that must be resolved before faculty with practical experience will be encouraged to join (and stay) with engineering programs is that of promotion. While many Australian universities state that they give equal weighting to the areas of research, teaching and service in promotion considerations, this is often felt to be lip service when the lists of faculty promotions are viewed. Until the universities not only say that they value teaching and practical experience but are seen to be backing that up with promotions, such faculty members will not stay to provide their valued input to students, but will return to industry where they will be more adequately rewarded financially.

#### Critical Issue No. 6

*The existing teaching and learning strategies or culture in engineering programs are outdated and need to become more student-centred.*

Engineering programs are probably notorious as being some of the most traditional of all university programs with regard to teaching and learning, with lecturing and closed-ended problems being the overwhelming norm. The effectiveness of this process is succinctly described by Felder and Brent (1996):



... much of what happens in most classes is a waste of everyone's time. It is neither teaching nor learning. It is stenography. Instructors recite their course notes and transcribe them onto the board, the students do their best to transcribe as much as they can into their notebooks, and the information flowing from one set of notes to the other does not pass through anyone's brain... (p. 3)

Why do the majority of engineering programs persist with the lecture mode of teaching when considerable research has shown that it is ineffective? As stated previously, there is often a financial argument cited as the reason for retaining lectures as the primary teaching mode. From an administration point of view, they are efficient with lots of students, only one room and one faculty member required at a time and the necessary information is transferred. However, if the efficiency equation is expanded to incorporate the effectiveness of the learning outcomes, then lectures probably move to the bottom of the list.

Another commonly stated reason given for persisting with outdated teaching methods is that this was how the current engineering faculty were taught themselves, so if it worked well for them, why shouldn't it work for the current students? Unfortunately, this thinking ignores the fact that the faculty may not learn in a way that is typical of the majority of their students. Maybe they succeeded at university and remained or returned to pursue academic careers because a passive, introspective learning style was their preference (and of course there is always the old adage applied to many occupations, "Those who can do, do. Those who can't do, teach.", maybe the faculty were not suited to succeed in industry). Teaching and learning styles have been extensively discussed by Richard Felder and others, and they assert that some engineering lecturers will need to undergo radical changes in their teaching styles. Felder and Silverman (1988) argue that these changes must take place or potentially excellent engineers will be lost at undergraduate level:

Learning styles of most engineering students and teaching styles of most engineering professors are incompatible in several dimensions. Many or most engineering students are visual, sensing, inductive and active and some of the most creative students are global; most engineering education is auditory, abstract (intuitive), deductive, passive and sequential. These mismatches lead to poor student performance, professorial frustration, and a loss to society of many potentially excellent engineers. (p. 674)

What measures can be implemented to overcome these problems? One of the most obvious is to educate engineering faculty about teaching and learning. Organisations such as the American Society for Engineering Education (ASEE) and the Australasian Association of

Engineering Education (AAEE) have been founded (ASEE over 100 years ago) to promote discussion and knowledge development about education issues for engineering educators. They publish journals, run conferences and short courses, but are often preaching to the converted, those faculty who already realise that it is important for them to think about education processes and practices rather than just content in their teaching. However, they do provide a valuable support network for those faculty members, and development opportunities for those faculty who wish to learn more. Some universities are encouraging staff to undertake further training in education. For example, the University of South Australia has offered scholarships to its engineering and computing staff that will cover the cost of undertaking a Graduate Certificate in Higher Education, by distance education mode. (Unfortunately they were not overwhelmed with applicants). Other universities, for example the University of Texas through Jim Stice (Stice, Felder, Woods & Rugarcia, 2000), have implemented courses in post-graduate programs, so that those students who may be acting as tutors and will potentially become lecturers receive some training in teaching and learning issues.

The clear response to teaching and learning strategies that have been shown to be ineffective is to use different strategies. The general consensus is that these strategies must be student-centred and several variations on this theme are suggested, with the most common being problem-based learning and project-based learning, which are discussed in greater detail in the following chapter. Other terms used are active learning, co-operative learning and student-centred instruction. The thrust of all of these strategies is that they demand active involvement of the student, and the teacher's role becomes that of a guide or mentor, rather than the fount of all knowledge. This can be quite a threatening idea for many faculty members. Fears such as loss of control of what takes place in the learning environment, that they will not cover the content and even that they might be led into discussions of areas in which they are not expert, and their concern over acknowledging this to the students, can prevent many faculty from taking steps in the direction of student-centred learning. However, according to Felder and Brent (1996), persistence in these methods will reap rewards "in more and deeper student learning and more positive student attitudes toward their subjects and toward themselves. It may take an effort to get there, but it is an effort well worth making." (p. 7)

## **Summary**

Revised course accreditation criteria through ABET, SARTOR and the IE Aust. mean that all engineering institutions in the USA, UK and Australia will need to develop revised program and course structures, and teaching methods, to help their graduates to acquire the

industry desired skills and qualities in the future. Most institutions will probably choose to gradually modify their existing programs, constrained by financial considerations, tradition and the expertise and experience of their existing faculty. Others may adopt a more radical approach by shifting the fundamental basis of their education approach to a project- or problem-based learning model. Prados (1998) proposes such a model:

A new engineering education paradigm is needed, characterized by active, project-based learning; horizontal and vertical integration of subject matter; introduction of mathematical and scientific concepts in the context of application; close interaction with industry; broad use of information technology; and a faculty devoted to developing emerging professionals as mentors and coaches, rather than as all-knowing dispensers of information. An engineering education based on this vision should not only produce graduates better prepared to meet the needs of engineering employers, but could very well increase student motivation and interest, with a consequent reduction of the present high dropout rates. (p. 2)

The foregoing discussion has focussed on the broad issues relevant to engineering education in general. Issues of particular relevance to structural engineering education will now be examined.

## **Structural Engineering Education**

### **What is Structural Engineering?**

Structural engineering, one of four main specialist areas of civil engineering (the others are geotechnical, water, and transportation engineering), may be defined as:

...the science and art of planning, design, construction, monitoring and inspection maintenance, rehabilitation and preservation, demolishing and dismantling of structures taking into consideration technical, economic, environmental, aesthetic and social aspects. The term "structures" includes buildings, bridges, in-ground structures, footings, frameworks and any other structures composed of any structural material. Structural Engineers form a group of professionals who, through their education, training and experience, are suitably qualified to carry out such works. (IE Aust, College of Structural Engineers, 1998, p.1)

In Australia, structural engineers are generally employed in either design consultancy companies (some well known examples include Connell Wagner, Ove Arup, Sinclair Knight Merz) or with construction companies. Employment in government entities in Australia as a structural engineer is now quite rare.

### **Structural Engineering design**

The word *design* is used to mean many different things to different professions and occupations. It is commonly used in relation to artistic pursuits such as graphic design, fashion design and interior design. The use of the word within the profession of engineering is also very broad. To mechanical and industrial engineers, *design* is used in relation to the invention, development and production of a product or process, most commonly a discrete object, for example, a new gear assembly. Dym and Little (2000) provide a formal definition along these lines:

Engineering design is the systematic, intelligent generation and evaluation of specifications for artifacts whose form and function achieve stated objectives and satisfy specified constraints. (p. 8)

A less formal description is provided by Johnston et al. (1989):

Design is central to the philosophy of engineering. It is the basic engineering activity. Accomplished despite huge gaps in knowledge, it ranges from the development of computer software or consumer goods to the planning of construction work or the organisation of a factory or production run. (p. 229)

However, none of these meanings of the word encompass what structural engineers mean by *design*. Design is the “central activity of the structural engineering profession” and design skills are “at the very core of a structural engineering career” (Eyre, Morreau, Croll & Addis, 1994, p. 232.). To structural engineers, “design is both a verb and a noun” (Addis, 1990, p.2). Design is what engineers do when they develop the schemes for construction of a bridge or building, deciding how it will support the loads to which it will be subjected, whilst remaining safe and serviceable for its occupants, yet also retaining the external appearance required by the architect. Design is also the products (usually drawings, backed up by calculations) that come from these decisions and which are used to communicate the *design* to those who will actually build the structure.

Harris (1975) has summarised this as “the determination of what is to be built and the preparation of the instructions necessary for building it.” (p. 17) He goes on to state that

when undertaking design, “The factors which the engineer has in mind when designing are threefold: function, economy and safety.” (p. 18)

Design is mistakenly considered by some to be only putting theory into practice. Those who hold this view believe that the application of a correct mathematical structural analysis will enable the accurate prediction of the stresses and strains in a structure under load and the design of the structural members can then follow. However, practising structural engineers know that there is no such thing as a correct mathematical structural analysis, only an analysis that models the actual structural behaviour more closely than another analysis. Good structural design also depends on numerous other factors or types of knowledge apart from mathematical analysis, including rules of thumb, the numerous empirical data and rules associated with Codes of Practice, the properties of particular materials, factors of safety, intuitive knowledge of structural behaviour, experience and engineering judgement. (Addis, 1990, p. 11)

Hence successful structural design requires an engineer to possess theoretical, practical and experiential knowledge. But also certain skills are required, which are possessed to different degrees by different engineers. Ideally, a design team will incorporate people with strengths in each area. Addis (1990) describes the three main areas of skill required in an engineering team as the ability to come up with innovative and highly appropriate structural solutions to both familiar and new problems, the ability to take a design from a basic or general concept to the level of fine detail design, and the ability to create designs which can be built easily and cheaply.

If structural engineering design is seen as a set of skills that need to be developed and a range of knowledge that needs to be learned, this can be used to develop a framework for engineering education that is appropriate for future structural engineers. Addis (1990) summarises this as follows:

If it be accepted that “theory” does not lead or direct “practice”, and that engineering design be not merely “putting theory into practice”, then engineering education should incorporate an increased concentration upon design as the central activity of engineering. It should include design as an identifiably distinct skill which needs to be nurtured and developed separately...there would be benefit in introducing the notion of the design procedure to students of engineering..... A direct approach to the understanding of structural behaviour is also to be encouraged, rather than relying on the dubious assumption that such understanding necessarily follows from learning the mathematics of structural analysis. (p. 202)

Although design is the primary role of structural engineers, there is continued concern that it is not properly taught or given sufficient emphasis in current university programs (e.g., Beaufait, 1993; Tietz, 1997). A major part of the problem is that many faculty who have been career academics, have little personal experience in doing design in practice (e.g., Suprenaut, 1987; Lahoud, 1990). Design was traditionally taught in an experiential mode, as is very commonly seen in architecture programs. Design was often seen as a soft course by the engineering scientists who felt that they taught the real content. However, there is increasing pressure from professional accreditation bodies and some engineering academics to increase the design emphasis in all engineering programs, including structural engineering. Dym (1999) asserts that design taught in a project-, team-based approach addresses many of the concerns of accrediting bodies and practitioners. “It helps engineering students develop skills in some of the related ‘arts’ of being an engineer, including working in teams, making presentations to a variety of audiences, and managing design engineering projects.” (p. 146)

### **Structural Engineering education – current practice and issues of concern**

Structural engineering forms a specialisation under the broad category of Civil Engineering. In Australia, training in structural engineering is undertaken as part of a four-year Bachelor of Engineering (Civil Engineering) degree, which also incorporates training in the other specialist areas of geotechnical, water and transportation engineering. Postgraduate study is available at several universities, specialising only in structural engineering, but this is not commonly undertaken at present. The majority of practising structural engineers in Australia have completed undergraduate degrees only and rely on experience gained in practice for their further training. The situation is similar in the UK and USA, although Master’s degrees for professional registration are becoming common in the USA, primarily because a US Master’s degree is similar to a Graduate Diploma in Australia, since students enter

undergraduate degree programs with a lower mathematical and science base, (see for example University of Missouri-Rolla, 2001). In many countries in Europe, there are three-year Diplomas/degrees (nomenclature varies), but engineers intending to practice in structural design would normally complete a five-year degree. In countries such as China, undergraduate degrees are specialised and it is possible to undertake a Bachelor of Structural Engineering degree.

The typical structural engineering specialisation within the majority of civil engineering degree programs involves two streams of courses. One relates to the physics and mathematical modelling of structures and how they behave, and the other relates to the behaviour of the various construction materials and how they are utilised in structures. The first course group is frequently labelled *structural analysis* and the second *structural materials or design*. Different universities place different emphasis on each stream, and design projects are also given varying emphasis within the second stream. It is rare that the analysis and materials streams are synthesised. Examples of structural engineering course streams from three universities with strong engineering programs are provided in Tables 2.5, 2.6 and 2.7.

**Table 2.5 – Structural engineering program stream at Adelaide University (2000)**

<b>ADELAIDE UNIVERSITY – (minimum of 24.5 credit points of 96 in total program)</b>		
<i>Course name</i>	<i>Level</i>	<i>Credit points</i>
Statics and Dynamics	1	3
Materials 1	1	1.5
Strength of Materials IIA	2	3
Structural Design IIA	2	2
Structural Design IIB	2	2
Structural Design III (Concrete)	3	3
Structural Design III (Steel)	3	3
Structural Mechanics IIIA	3	3
At least 2 of the following:	4	2 per course
Advanced composite steel and concrete construction		
Advanced steel design		
Computer methods of structural analysis		
Design of concrete structures		
Earthquake engineering		

**Table 2.6 – Structural engineering program stream at Purdue University (2001)**

<b>PURDUE UNIVERSITY – (minimum of 31 credit points of 133 in total program)</b>		
<i>Course name</i>	<i>Level</i>	<i>Credit points</i>
Basic Mechanics I Statics	2	3
Engineering Materials 1	2	3
Introduction to Structural Mechanics	2	4
Basic Mechanics II Dynamics	2	3
Engineering Materials II	3	3
Structural Analysis I	3	3
Structural Analysis II	3	3
Structural Design in Metals	3	3
Theory of Reinforced Concrete	4	3
Architectural Engineering	4	3

**Table 2.7 – Structural engineering program stream at MIT (2001)**

<b>MIT – (course credit points not stated)</b>		
<i>Course name</i>	<i>Level</i>	<i>Credit points</i>
Solid Mechanics	2	
Civil Engineering Materials	2	
Structural Engineering Design	3	
Structural Analysis and Control Mechanics	3	
Mechanics and Design of Concrete Structures	4	
Mechanics of Materials in Civil Engineering	4	
Mechanical Vibrations (elective)	3 or 4	
Mechanics of Structures (elective)	3 or 4	

However, there are shortcomings to this traditional approach in preparing students for professional practice on graduation. Addis (1990) asserts that civil and structural engineering teaching is now almost wholly approached by the use of mathematical models of reality, commonly termed *theory and structural analysis*. However emphasis is given to the manipulation of the models and the derivation of solutions from them, with very little consideration being given to how the models relate to, or how well they describe the behaviour of, real structures. Addis believes that students are not told how to use mathematics and engineering science in design situations and that students are also not



taught about the other types of knowledge used in engineering design, such as those discussed earlier. Finally, students are also poorly taught with respect to the limitations of the theoretical approach, and when it might actually be necessary to conduct tests on physical models.

Addis also cited earlier statements from several eminent engineers in support of his argument, including Harris (1980) – “If students are taught solely the theory which lies behind a practice of which they learn nothing, they conclude that only the theory is important.” (p. 409) and Brohn and Cowan (1977a) – “Many of our present graduates do not have that familiarity with structural behaviour which should be demanded from them if they are to meet minimal professional standards.” (p. 9) These thoughts also were echoed by Eyre et al. (1994) – “Analysis, mechanics of solids, soils, fluids, material science, and all the other areas now crowding out engineering curricula are too often abstracted from it rather than treated as an integral part of design.” (p. 232)

Curricula from the United States, in particular, are heavily oriented towards engineering science and are delivered by faculty who are overwhelmingly the products of the same scientific research culture (Dym, 1999). This situation is perpetuated by the strict requirements for doctoral qualifications for all staff, and the institutionalised requirements for research as the means of gaining academic tenure and promotion. Many universities in Australia have been moving in the same direction, but their current staffing profiles still tend to include at least some staff with significant industrial experience, particularly at those universities that were originally technological institutes. If the recommendations of ABET (1999) and the IE Aust Review (1996a) are followed, then this staff profile incorporating a mix of both research and industrial backgrounds will, it is to be hoped, be retained in Australia and rejuvenated in the US.

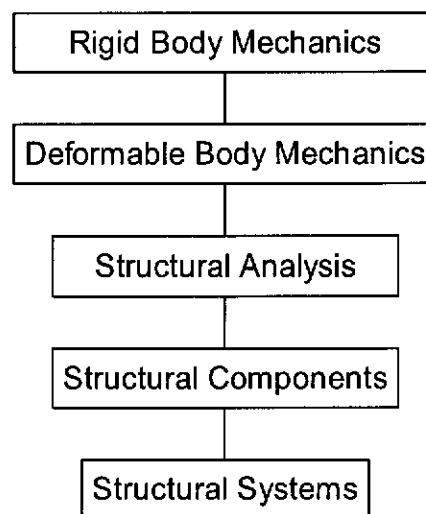
Instead of listing required courses for structural engineers and perpetuating the separation of analysis and design, Dym (1999) advocates that we should develop lists of skills and experiences that students require, derived from statements of what we want engineering graduates to be able to do. For example, “a student should be able to design a simple steel industrial building.”(p. 145) This requires that the student must identify and determine building loads and any environmental forces, relevant building codes and requirements, basic structural choices for framing and layout, structural elements and their models, techniques for analyzing the structure, and so on.

A student carrying out such a design project must also learn to read and interpret codes, read and interpret architectural drawings, interact with other engineering specialisations such as

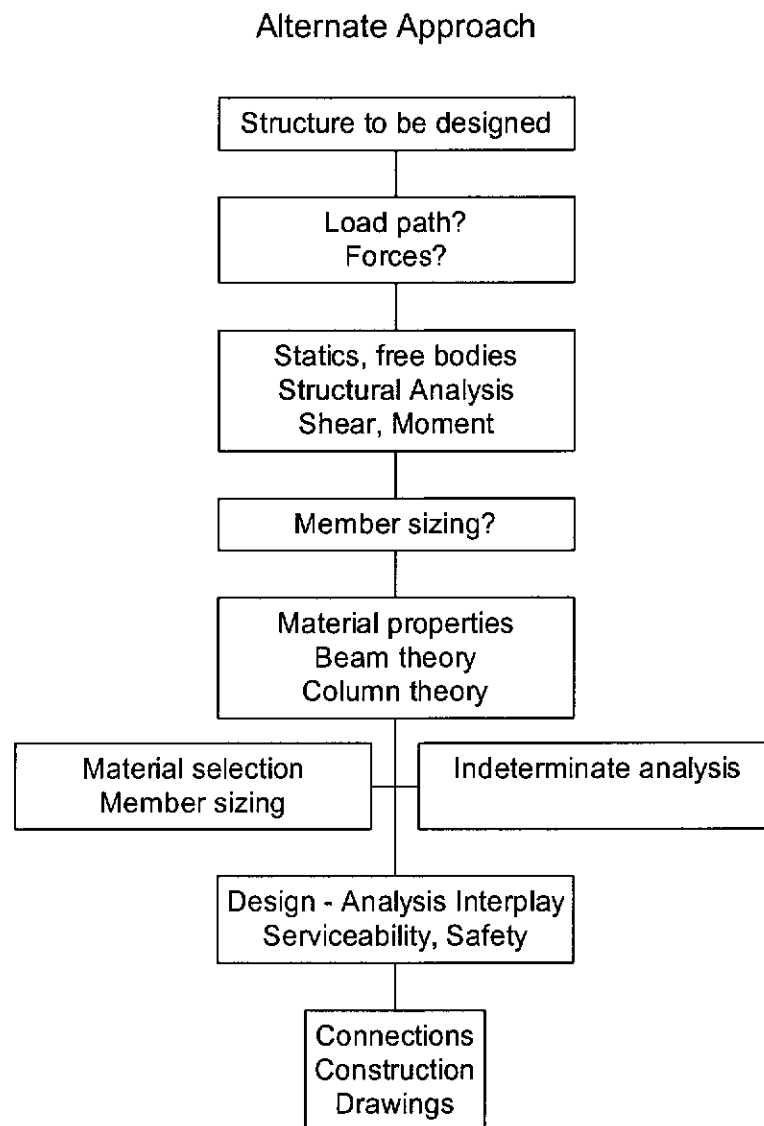
geotechnical engineers involved with the footing design and use standard computer packages for structural analysis and element design. However, Dym does not call for a wholesale replacement of analysis courses with design courses, since both are absolutely essential for engineering education and practice. “The point is that students have to learn engineering science so they can do design, that is, engineering science is taught to enable our students to do design.” (p. 146) The need for interconnection of structural analysis courses with design is also advocated by Bjorhovde (1993), Gerstle (1990), Tietz (1997) and Wright (1993), among others.

Gerstle (1990) proposes an alternative conceptual approach to the teaching of structural engineering using a series of design problems or projects. In Figures 2.1 and 2.2, Gerstle has summarised the conventional approach and his alternate approach respectively.

### Conventional Approach



**Figure 2.1 – The classical structural engineering training (adapted from Gerstle, 1990, p. 116)**



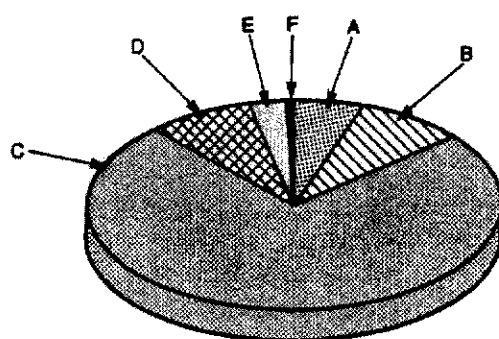
**Figure 2.2 – An Alternate Approach (adapted from Gerstle, 1990, p. 118)**

Several topics within current structural analysis syllabi are suggested as being obsolete by Taplin (1994), an Australian academic with ten years of consulting experience prior to lecturing. He argues that topics such as graphical methods of analysis, moment distribution, slope deflection and energy methods of analysis are obsolete for the practising structural engineer, although energy methods have a role in some research. These topics should be removed to make way for the teaching of a conceptual understanding of structural behaviour, which is best developed by an understanding of deformation and stiffness, as discussed by Brohn (1992).

As stated earlier, one of the issues that is holding back the increased emphasis of practical design experiences in all engineering curricula, is the lack of personal experience of faculty in this area. (Tietz, 1997) Suggestions are often made that industry practitioners must increase their direct involvement in design courses to provide this experience (see for

example Beaufait (1993); Bjorhovde (1993); Bohinsky & Lee (1994)), but unfortunately, due to the economic constraints under which many modern consultancies operate, this often does not occur. The use of recently retired engineers in this role would seem to have considerable merit, and should only require coordination between universities and their local branch of the relevant learned society such as the Institution of Engineers, Australia. However, the counter-argument is made by some academics that the development of intuitive understanding of structural behaviour and practical design is entirely the responsibility of those in charge of the graduates in their early professional experience. (Brohn & Cowan, 1977b; Shaari & Ramli, 1990, p. 65)

Another issue that also may be contributing to the lack of integrative design education in structural engineering is the nature of the textbooks on structural design. Cairns and Chrisp (1996) analysed the contents of typical design textbooks in structural steelwork (see Figure 2.3).



- A – Metallurgy and properties of material
- B – Description of production processes (including manufacture, welding, fabrication, erection, corrosion and fire protection)
- C – Methods for the calculation of strength/size of structural elements and connections
- D – Influence of structural form on element and connection behaviour
- E – Case studies and historical perspectives
- F – Process of design

**Figure 2.3 – Contents of typical design textbooks in structural steelwork (from Cairns and Chrisp (1996), p. 376)**

Cairns and Chrisp found that the bulk of the text was concerned with detailed assessment of strength capacity of individual structural elements according to the relevant Code of Practice. The design problems in the text were tightly defined with limited discretion given to the student, their task being to replicate solutions derived in earlier worked examples in the text. In this respect, many textbooks titled *Design* differ little from those entitled *Analysis* (p.

376). These findings were echoed by Miller and Olds (1994), who stated that many *design* courses treat design as:

Solving well-defined, discipline-specific problems which differ from engineering science exercises only by having multiple possible solutions. The widespread acceptance of this design model is illustrated by the number of engineering design texts available in various disciplines complete with 'answer' books for faculty use. (p. 311)

Ellifritt (1994) also makes the point that most design textbooks do not treat the topic of loads adequately. "Students get used to seeing structural members as lines and loads as arrows with some magnitude shown at the tail. How the arrow got there and if the load is correct is usually not their concern." (p. 1364) Yet, in practice, the determination of the load values on a structure, and how they are distributed through a structural system to individual structural members, will be far more important (in terms of efficient and economic design) and probably a more time consuming phase of the design than sizing the members to support those loads, which is the primary focus of most design texts. There have been some recent additions to the design text library that discuss the practical issues of design in a much broader sense and provide more open-ended examples, such as Dym and Little (2000).

Evidence to support Ellifritt's concern over the topic of loads was provided from a survey of ABET-accredited programs in civil and architectural engineering in the USA by Schmidt (1994). He found that the average lecture hours dedicated to loads in the 122 institutions that responded was 10.0 hours: "66% of all respondents were satisfied with their coverage of loads and 34% were not." (p. 1361) He also reported some more general statistics on structural engineering course requirements:

95% of all programs require a course in structural analysis, 30% require a course in structural systems, and 25% require both. Steel design is required in 74% of all programs and concrete design is required in 71%. Courses in both steel and concrete design are required by 62% of the programs and only 7% require a single course that deals with design in more than one material. (p. 1361)

Of particular concern were the comments provided by those respondents who felt that loads were unimportant, and who gave the topic a cursory treatment at most. These included: "I am satisfied. One cannot afford to focus on the issue of loads."; "In engineering design practice they will learn all the details they need. We don't waste precious undergrad time with such details" and "Based on the current number of hours allowed to the structural

engineering and design classes, I do not intend to change in the future. Too many other topics are important!" (p. 1362) Fortunately, Schmidt's overall findings were that the trend was towards a greater emphasis of loads in undergraduate structures courses than previously.

Some additional concerns about current structural engineering education are expressed by Lahoud (1990). These are the lack of a minimum level of training in basic skills such as drawing procedures, steel and concrete detailing and the relationship between drawings and specifications. Many of these concerns can be addressed by including them within design projects, although, again, Lahoud points to the lack of experience of most faculty in this area. His second concern is the lack of education in the legal responsibilities and limitations of the designer. Lahoud suggests that this would best be dealt with through the provision of short courses from societies such as the ASCE or by employers themselves.

Although many of the authors quoted here are referring to the USA experience, the situation in Australia is only marginally better. Students entering university with Year 12 Mathematics and Physics start approximately a year ahead of most of their US counterparts, where calculus, for example, is not covered in the standard high school mathematics curriculum and physics is not part of the required science stream (see for example University of Missouri-Rolla, 2001). Students with a focus on engineering careers *may* undertake advanced Mathematics and Physics at high school, but these are not assumed as prerequisites for college engineering degrees. As a result, the minimum required credit points of structural engineering offered in Australian degrees is usually as much or more than the maximum amount offered by taking a structural engineering specialisation in US degrees. (Due to their smaller engineering student cohorts, Australian universities are generally unable to offer significant specialisations at undergraduate level.) However, the proportion of structural engineering in Australian civil engineering degrees has certainly decreased in the majority of universities in recent years owing to increased emphasis on management, humanities and environmental subjects arising from revised accreditation requirements. The lack of practical design experience of faculty members is also a growing concern in Australia, and has contributed to the fact that the parts of the structural engineering curriculum that have been sacrificed in many cases are the practical aspects, such as detailing of steel and concrete structures.

It is to be hoped that many of these concerns will be addressed when (or if) revised accreditation requirements are implemented in civil engineering programs. These will require an integrated design approach throughout the program, including the structural engineering specialisation.

## **What does industry want from Structural Engineering graduates?**

There have been several studies undertaken on the needs of industry from engineering graduates in general, as discussed earlier. There is also some literature specific to the needs of the structural engineering industry, but not a broad survey. Bohinsky and Lee (1994), senior consultants with the multi-national consultancy firm Brown and Root, assert that:

For engineering graduates to perform well in design firms, it is very important that Universities provide them with a strong theoretical background that is vital for sound engineering judgement in solving complicated problems. It is equally important that universities teach them practical applications that will enable them to accomplish day to day engineering design work. (p. 1353)

A principal of his own consulting firm, Lindsey (1993) puts his needs from graduates into commercial perspective, "First and foremost, most practising engineers are in the business of making money. Secondary to that is the pursuit of engineering excellence. Any student that comes to work must become productive quickly." (p. 1654) His four most important requirements for a structural engineering graduate are that they must be totally computer-literate, understand structural behaviour, exhibit a willingness to continue learning, and have an ability to successfully interact with people.

Coil (1993) provides a very specific list of technical skills that he expects from graduate engineers entering his structural engineering consulting practice, which can be summarised as follows:

- Understanding of basic concepts of various building systems along with the general advantages and limitations of each.
- Ability to establish simple framing systems and determine the loading on the various elements, members and connections in the system due to gravity, wind, snow and seismic loads.
- Ability to determine the deflected shape of the structure under various loading conditions and how a change in the geometry or connection details will effect this.
- Understanding of the physical properties and performance characteristics of the basic construction materials such as steel, concrete, wood and masonry.
- Understanding of the characteristics of different types of soils, foundation systems, and earth loads on retaining structures. (p. 1650)

The most formal guidance on what industry requires from graduate structural engineers is provided by the legal registration requirements for practice and the membership requirements of the relevant specialist learned societies in each country. Registration for professional practice as a structural engineer is not yet universally required in Australia, but several Australian states have adopted registration on the National Professional Engineers Register (NPER), in the practice area of structural engineering, as satisfying their legislative requirements in this area. Membership of the Structural College of the Institution of Engineers, Australia is also considered as full professional standing in structural engineering. The Institution of Engineers, Australia is also accredited to assess eligibility for registration on NPER, hence their guidelines for assessment can be considered to satisfy both standards. The Institution of Engineers, Australia, College of Structural Engineers has produced a set of *Guidance Notes for Membership Reviewers* (2000, see Appendix A2) for this purpose. Although one of the requirements of the applicant is that they have a minimum of three years practical experience in structural engineering since graduation, the guidelines can be used as an indication of the expected knowledge of a graduate engineer, particularly in the categories relating to *Engineering Planning and Design* and *Materials/Components/Systems*. (Most of the other categories specifically refer to the professional work experience of the applicant). The items in these categories relate very closely to those cited by the authors above, for example:

- Have an understanding of loads (gravity, earth, wind, earthquake, fire, etc.) and how their effects are modelled in structural analysis.
- Understand the importance of stability, strength and serviceability.
- Understand the need to produce engineering solutions that are functional and economical as well as technically correct.
- Have good knowledge of the properties of each of the materials normally used – steel, concrete, masonry, timber, soil and rock.
- Understand the need for alternative load paths and the need to avoid progressive collapse mechanisms.
- Have the ability to ‘visualise’ failure mechanisms.
- Have a good knowledge of modern techniques of structural analysis, design and construction.
- Have a broad knowledge of relevant Australian Standards.



- Have knowledge of available analysis and design aids including computer programs and steel, concrete and masonry manuals.
- Have short-cut methods to check computer outputs.
- Understand ductility, brittleness, rigidity and flexibility and their effect/contribution in material failures.

The Institution of Structural Engineers (IStructE) has produced a similar set of guidelines in the United Kingdom. In their case these guidelines are used to assess whether a candidate is ready to sit the seven-hour examination they require for full membership of the Institution, which would usually be after a minimum period of three to five years professional experience after graduation. However, although the examination is not required for legal practice as a structural engineer in the UK, it is recognised worldwide as indicative of significant proficiency in structural engineering. For legal practice in the UK, the requirements are registration as a Chartered Engineer by the Engineering Council, which is usually assessed by submission of an experience report, a project report, an interview and a written assignment. (Engineering Council, 2000; Institution of Civil Engineers, 2001)

The IStructE guidelines list a set of compulsory core objectives in which a minimum level of competence must be achieved (IStructE, 2000). The competence levels range through ability, experience, knowledge and appreciation, with ability being required in the core structural engineering objectives, which are very similar to those developed by the College of Structural Engineers in Australia.

## **Summary**

The needs of the structural engineering industry sector of the engineering profession, and the issues and challenges for the education of undergraduate engineers able to join that sector are similar to those of the general profession. In particular, the integration of specific technical knowledge and application of fundamentals in practice are critical, and one of the best means of achieving this is through an increased emphasis on realistic and integrated design exercises in the undergraduate curriculum. The literature relating to structural engineering education, and from the related industry studies, in particular the guidance from the professional registration bodies such as the Structural College of the Institution of Engineers, Australia, has been used to develop a response to the first research question of this study – What do students of structural engineering need to learn in order to be able to design/construct engineering structures when they enter professional practice?

# Chapter 3: Problem-based and project-based learning

## Introduction

Problem-based learning has been suggested by many as a solution to the engineering education issues discussed in the previous chapter, and it has been implemented to a limited extent in some engineering programs. Others suggest that project-based learning is more appropriate for engineering. The following review of the literature will define what is meant by both problem-based and project-based learning, why they are used, and how and where they have been implemented to date, focusing particularly on engineering examples. This review will be used in the next chapter to define the nature of the project-based learning that was the basis of this study and will provide some examples in answer to the second research question of the study - How can these learning requirements be implemented through a project-based curriculum? The discussion will also examine the success and effectiveness of each model, compare them in an engineering context, and consider the difficulties that arise in implementing a problem- or project-based curriculum in engineering. Some of the evaluation of existing programs will provide a partial answer to the third research question - What do engineering students perceive as the relevance of project-based learning to the professional practice of structural engineering? A more detailed answer to this question will be provided by the current study.

## Problem-based Learning

Problem-based learning was introduced for professional training in medicine in the 1960's in Canada and the USA and is now used extensively in that field. It has also been implemented in related health professions. It has been succinctly defined by Boud and Feletti (1997):

PBL is a way of constructing and teaching courses using problems as the stimulus and focus for student activity... It is a way of conceiving of the curriculum as being centred upon key problems in professional practice. Problem-based courses start with problems rather than with exposition of disciplinary knowledge. They move students towards the acquisition of knowledge and skills through a staged sequence of problems presented in context, together with associated learning materials and support from teachers.

(p. 2)

Woods (1994) describes traditional or subject-based learning as a structure where the subject discipline drives the learning and subjects are learned in isolation from each other. The assumption is made that learners know nothing, or very little, about the subject and they are presented with what the teacher thinks they need to know. On the other hand, in problem-based learning, students' prior knowledge is acknowledged and each student determines what he or she needs to know, then proceeds to learn it and apply it, with the teacher acting as a mentor or guide.

Problem-based learning has been adopted in Australia, Canada, Europe and the United States, but has not made a significant impression in Asia to date (although Joson (1996), cited in Boud and Feletti (1997), has reported on a problem-based learning curriculum in medicine in the Philippines). Several reasons have been given by various authors for the adoption of problem-based learning in professional education (Aldred, Aldred, Walsh & Dick, 1997, p. 2), including perceived deficiencies in "traditional" professional education (Barrows, 1986; Berkson, 1993; Boud, 1985); a need to be able to cope with the demands of the information explosion in many areas of professional knowledge (Berkson, 1993; Boud & Feletti, 1997); the need for professionals to be able to adapt to change and communicate effectively (Boud, 1985); and the need to acquire the skills for lifelong learning (Barrows, 1986; Woods, 1994).

There are numerous variations on the problem-based learning theme that have been implemented in practice, and authors differ as to whether or not these constitute problem-based learning. Barrows (1986) classified the varieties of problem-based learning in medicine using a taxonomy. He identified six varieties of problem-based learning and then rated them in terms of how effective they were in achieving four outcomes, namely, structuring of knowledge for use in clinical contexts, development of effective clinical reasoning process, development of effective self-directed learning and increased motivation for learning. The six varieties that Barrows identified ranged from lecture-based cases, which he rated as low in all four outcomes, through to case method, rated as average in all four outcomes to closed-loop problem-based, which was rated as high in all outcomes.

Another taxonomy or classification system for individual courses developed by Hadgraft and Prpic (1999) defines five key dimensions for problem-based learning – problem, integration, teamwork, problem solving and self-learning – and four steps on a continuum with respect to their implementation. This system is described in Table 3.1.

**Table 3.1 – Key dimensions of Problem Based Learning (from Hadgraft & Prpic, 1999, p. 129).**

Step	Problem	Integration	Teamwork	Problem solving	Self-learning
1	Several problems per week	No or little integration of concepts. A single skill or idea	Individual work	No formal problem solving methodology. Students concentrate on learning how to solve each new class of problem.	Lecturer provides all the content via lectures, notes, web pages, tutorials, references to books and journals. Students concentrate on learning what has been given to them.
2	One problem per week	Some integration of concepts	Students work together informally in classes but submit individual work.	Formal problem solving methodology which is applied in lectures.	Lecturer provides much of the content, but expects students to find some details and/or data for themselves.
3	More than one problem, each for several weeks	Significant integration of concepts and skills in the solution of the problem.	Teamwork, but less formal than the next category. Joint report, but no peer evaluation.	Formal problem solving methodology which is closely supervised by tutors in tutorials.	Lecturer provides a textbook as the basis for the subject, but expects students to engage with it and with other materials in their own way.
4	One problem per semester	Major integration, perhaps including more than one discipline.	Formal teamwork, team meetings, peer evaluation, joint report.	Formal problem solving (and learning) methodology. Students apply this method by themselves to each new problem.	Lecturer provides little or no material (perhaps some references). Students use the library, Internet and experts to come to an understanding of the problem.

Using this system, Hadgraft and Prpic assert that a traditional lecture and tutorial-based course would probably be classified as 1, 1, 1, 1, 1, while a research degree might be 4, 4, 1.5, 1, 4 and a typical capstone design project course in engineering probably as 4, 4, 1, 1, 3 (although the capstone design project course that is taught at the University of South Australia would be classified as 4,4,4,1,4.)

However, according to Engel (1997), the use of individual problem-based learning courses in a program that also includes traditionally taught courses does not constitute a pure form of problem-based learning that will consistently support effective adult learning (p. 19). He states that it is not possible for separate, course-centred groups of academics to plan, organize, implement and evaluate a problem-based curriculum. A problem-based curriculum requires that no course or topic should be studied in finite depth at any one time, but should be reintroduced repeatedly with increasing sophistication whenever it contributes to the problem being studied. It also requires that courses should not be presented separately but should be available for study as they relate to a problem.

While problem-based learning has been used to deliver complete degree programs, as espoused by Engel, others describe a range of practices as forms of problem-based learning. Woods (1994) includes a research project, a case method, a design project, a clinical encounter, or a self-directed, self-assessed, small learning group as problem-based learning (p. 2.2). Hybrid models of problem-based learning are described by Boud and Feletti (1997,

p. 3) at institutions such as Case Western Reserve University, which uses a wide range of instructional methods and strategies, and at Harvard Medical School where problem-based tutorials, lectures, conferences and clinical sessions are used to integrate teaching and learning around weekly themes. Bouhuijs, Schmidt and Van Berkel (1993) consider problem-based learning to be “an educational strategy aiming at various educational goals and employing various formats.” (p. 9) Feletti (1993a) introduces the term problem-based curricula (PBC) to describe the type of model advanced by Engel, and examines the academic research on PBL versus PBC.

There is general agreement though on the fundamental strategies or themes of problem-based learning (e.g., Barrows, 1996; Boud & Feletti, 1997; Bridges & Hallinger, 1998; Hadgraft & Prpic, 1999). These are that learning is student-centred not teacher-centred, that students identify their own learning needs and learning usually takes place in small groups with faculty acting as tutors or guides. The problem is posed first, provides the focus and stimulus for learning, and assists in integrating knowledge, with the problem presented as a simulation of professional practice.

There is also general agreement on the educational objectives that can be achieved using problem-based learning. These include (e.g., Barrows, 1996; Bridges & Hallinger, 1998) the acquisition of an integrated knowledge base, the acknowledgement and use of students' prior knowledge, the development of team and communication skills, the development of effective self-learning skills and the acquisition of a knowledge base that uses the problem-solving processes employed in the professional practice of the discipline being studied.

Whilst there is general agreement on what makes up problem-based learning and the educational objectives it strives to achieve, Cowdroy (1993) has taken the opposite line and developed a set of *myths* of problem-based learning, to assist those institutions that may be considering its introduction. According to Cowdrey, the *myths* of PBL are that it works only for sophisticated educational disciplines, it is simply co-ordination of study disciplines, it means that all learning has to be by tutorial, it means less time for study disciplines and therefore lower quality of learning, it is a timetabling nightmare as all learning and problem solving must occur simultaneously, it means loss of objective assessment, and loss of academic autonomy in content and method.

However, if an institution is considering the introduction of problem-based learning to only some courses whilst retaining traditional teaching method in others, Kenley and Dodds (1995) warn of some of the problems that may eventuate. These include that students suffer a loss of direction in the PBL courses because they are accustomed to structured programs

and hence fail to make adequate progress as they are used to the lecturer setting schedules. Other problems may be that students resent the workload, the good students thrive on self-learning, the poor students fail to achieve, the students blame the lecturer for any lack of achievement, standardised student evaluations of teaching in these courses receive low results and problem-solving becomes course-specific and narrow.

To counteract these issues, Woods (1997) of Chemical Engineering at McMaster University instituted training workshops for the students to increase their confidence and skill in teamwork, problem solving and self-assessment, and to help them cope with the stress and dis-equilibrium they feel in experiencing such a different approach to learning. (pp. 174-5)

### **Applications of problem-based learning**

As stated previously, problem-based learning in its modern form is generally considered to have been developed in the medicine program at McMaster University in Canada, which graduated its first class from the program in 1972. Other medical programs at Maastricht University (Netherlands) and the University of Newcastle (Australia) followed suit in the early 1970's (Barrows, 1996) and problem-based learning has since spread widely in medicine. Problem-based learning also has been adopted and accepted in other health professions such as occupational therapy, physiotherapy, orthoptics, nutrition and dietetics (Boud & Feletti, 1997), medical radiations (University of South Australia, 1996) and others. Some other areas of professional study such as agriculture, community nursing and social work have adopted modified versions of PBL, using terms such as issues-based learning, situation improvement or enquiry and action learning. Their curriculums are designed around key issues from practice and students learning collaboratively (Boud & Feletti, 1997, p. 8).

The application of problem-based learning to fundamental science or mathematics programs at university level is not yet common. This is despite the fact that research in K-12 science and mathematics education is increasingly advocating student-centred, active learning approaches, which could incorporate problem-based learning. However, Allen, Duch and Groh (1996) describe a problem-based learning model that has been implemented at the University of Delaware in introductory courses in biology, chemistry and physics. A problem-based learning framework has been used also in a teacher education course designed for students who are learning to teach year three to seven science in Australia (Peterson & Treagust, 1998).

In the building-related professions, architecture has adopted problem-based learning most readily. Many architecture programs already incorporate the design studio model of teaching which is a student-centred, discovery learning model, so a progression to problem-based

learning is fairly logical in this profession. However, in traditional architectural education the integration of supporting technical and theoretical areas are taught as separate courses, rather than being integrated with the design activity. The programs at Delft University of Technology (Netherlands) and the University of Newcastle (Australia) have been reported by Claessens, De Graaff, Jochems and Cowdroy (1995); De Graaff and by Cowdroy (1995) and Kingsland (1996).

De Graaff and Cowdroy (1995) provide information on the history of the Delft program. Delft had introduced a project teaching model at the end of the 1960's but faculty maintained their independent courses, and the program lacked cohesion, with some areas of technical study being neglected. After a negative report from a national review committee, a problem-based learning curriculum was hurriedly introduced to improve program performance. For several reasons – the implementation being a top-down decision imposed on the faculty, most of the faculty being unfamiliar with problem-based learning, the hurried nature of the implementation with a consequent lack of preparation and planning, and the structural reorganisation of staff that was required – the authors believe that the program has not been successful. An early compromise also was made due to the complaints of the design teachers, so that the program was implemented as a dual system – half problem-based learning and half design teaching. After six years, the program had effectively reverted to the previous model with design and theory-based faculty teaching their own individual courses.

By contrast, Kingsland (1996) describes the program at the University of Newcastle as very successful with excellent accreditation reports and external reputation. The program uses design projects as the central learning environment and integrates the four learning domains – professional, environmental, technical and theoretical – with the central activity of architectural design.

### **Why use problem-based learning in engineering?**

The answer to the question as to why problem-based learning should be used in engineering is fairly straightforward. Six critical issues for engineering education were proposed previously in Chapter 2:

4. Engineering curricula are too focussed on engineering science and technical courses without providing sufficient integration of these topics or relating them to industrial practice. Programs are content driven, rather than process driven.
5. Current programs do not provide sufficient design experiences to students.

6. Graduates still lack communication skills and teamwork experience and programs need to incorporate more opportunities for students to develop these.
7. Programs need to develop more awareness amongst students of the social, environmental, economic and legal issues that are part of the reality of modern engineering practice.
8. Existing faculty lack practical experience, hence are not able to adequately relate theory to practice or provide design experiences. Present promotion systems reward research activities and not practical experience or teaching expertise.
9. The existing teaching and learning strategies or culture in engineering programs is outdated and needs to become more student-centred.

When considering these issues it is clear that problem-based learning is a strategy that can be used to directly address numbers 1 to 4 and 6, and for it to be successfully introduced then issue no. 5 must also be dealt with. However, there are other student-centred teaching strategies that could also address these issues, so what is particularly relevant or useful about problem-based learning? De Graaff (1993a) points out that the value of using PBL in education depends on the type of professionals and nature of the profession. For professions involving highly specific technical expertise, or a body of unchanging knowledge that professionals must master absolutely, or where professionals usually operate alone, PBL may not be appropriate. However, "PBL works for professions with multidisciplinary background and a non-specialized interdisciplinary practice" (De Graaff, 1993a, p. 11), and this description can easily be applied to engineering.

As illustrated in the case of structural engineering, design is one of the fundamental processes and activities in engineering and basically all other engineering activities relate to it, for example, implementation or construction of designs or processes and maintenance of facilities or products. The strategy for teaching design, as has been practised in engineering programs for many years (although as stated in critical issue no. 2, not to a sufficient extent), has many similarities with the problem-based learning strategy. These similarities have been summarised by Williams and Williams (1994) in Table 3.2. Hence it would appear to be a logical extension of design education to implement problem-based learning, in a manner not dissimilar to the use of problem-based learning for architecture.



**Table 3.2 – Similarities between problem-based learning and teaching strategies for engineering design (based on Williams and Williams, 1994, p. 361)**

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<b>Similarities</b>
Both have a large number of phases or stages through which to pass during the project or problem.
Both start with an identified problem or situation, which directs the students' area or context of study.
Student initiated research is relied upon for the student to progress through the project as well as for their own learning.
Both require high levels of student initiative, students need to develop motivation and organisation skills.
Both lend themselves to long-term projects, PBL may be used over a short time frame but this does not detract from its ability to be used effectively over a longer time frame, as is usually associated with technology projects.
Both are open-ended with regard to outcomes, allowing the student the opportunity to choose, after appropriate research, an outcome that interests them.
Observational skills are identified as having a high priority, especially in the initial stages during identification of the problem.
Student reflection is an important aspect of both models, the student is encouraged to evaluate fully the outcome they have achieved.
Both rely upon group work.

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### **Existing applications of problem-based learning in engineering**

The use of problem-based learning in engineering programs has been reported by several authors, although the practice is still far from widespread. One of the better known applications has been in the Chemical Engineering program at McMaster University. (Woods, 1996; 1997; 1998; Woods et al., 1997) With a strong tradition of problem-based learning already developed in medicine at the same university, the Department of Chemical Engineering decided to implement it in their program in the early 1980's. However, they adapted the medical school problem-based tutorial approach to their own context, since they could not change the staff to student ratio, or the number of concurrent courses being taken by students. (Woods, 1997, p. 174) The problem-based learning approach as implemented in chemical engineering is used in two courses only, one at sophomore level, and the other in a senior design project course. It is carried out in class sizes of 20 to 45 with one faculty member, (rather than tutorial groups of five students per tutor as used in medicine), so in the engineering course, the students work in groups of five but with no tutor. To make this work successfully, McMaster uses a *Problem Solving Program* (see Woods et al. (1997) for a complete discussion of this), a series of workshops that have been embedded into four of the

chemical engineering courses spread through the years of the program. These workshops help students to develop problem-solving, interpersonal skills and team skills, which enable them to undertake the self-directed problem-based learning process in tutorless groups successfully. Hence the McMaster program in chemical engineering actually incorporates several student-centred teaching strategies and curriculum developments integrated across its program, of which problem-based learning is one component.

At Monash University, Australia, problem-based learning has been introduced to several courses in the civil engineering degree through the initiative of Roger Hadgraft. He has incorporated problem-based learning into second year computing and surveying (Hadgraft & Paget, 1990; Hadgraft, 1991); a third year course in systems engineering, and a post-graduate course in surface water modelling (Hadgraft, 1992); and a fourth year course in civil engineering computer applications (Hadgraft, 1995; Hadgraft 1997). The civil engineering department was gradually persuaded into adopting problem-based learning more widely into its curriculum and, in 1997 (Hadgraft & Prpic, 1997) ran a pilot project where one of four tutorial groups (25 students) in a structural analysis course participated in a problem-based learning course, while the other students completed the traditional course. Not unexpectedly, the pilot project highlighted a number of critical issues that had to be addressed prior to the widespread introduction of PBL into the course. Both students and tutors required training in the group processes required, as well as the self-directed learning philosophy of problem-based learning. Another issue was that faculty constantly judged the PBL group against benchmarks that had been set for the conventional stream, neither the students nor the tutors appreciated how different PBL is from traditional teaching methods (pp. 175-6). Despite this, Monash has persisted with problem-based learning, although in a modified form and this is discussed further as an application of project-based learning.

Other applications of problem-based learning in engineering that have been reported include courses in:

- Refrigeration and air-conditioning in the fourth year of Mechanical Engineering at Monash University (Akbar Hessami & Gani, 1993).
- Hydraulic Engineering in junior/senior level at Pennsylvania State University (Johnson, 1999).
- Computer-aided and manual drawing in first year Mechanical Engineering at RMIT (Katchalov & Milton, 1995).
- Design in second year Mechatronic Engineering at Curtin University (Rogers & Morgan, 1998).

- Water and wastewater engineering in fourth year Civil Engineering at Griffith University, Queensland (Lemckert, 1998).

In all of these cases, the implementation of problem-based learning has been to individual courses within a traditional engineering program, sometimes only one course due to the interest of the faculty member who teaches it, sometimes in a series of courses such as Woods at McMaster and Hadgraft at Monash, but again this is usually dependent on the interest and enthusiasm of an individual or small group of faculty.

According to some of the previous discussions and Engel's (1997) definition, this is not a true implementation of problem-based learning, as in Feletti's (1993a) problem-based curriculum. For problem-based learning to be introduced throughout a typical engineering degree, it would require interest, cooperation and integration of faculty from at least the engineering, mathematics, science and business/management divisions of an institution. This need for faculty cooperation is probably where one of the largest obstacles to full-scale PBL in engineering lies.

### **Does problem-based learning work in engineering?**

There are two ways to consider whether problem-based learning works in engineering. One is to look at evaluations of the effectiveness of those courses where problem-based learning has already been introduced; the other is a broader perspective that will be considered after this.

Evaluations of the effectiveness of problem-based learning programs in any field have been the subject of great debate in the literature, and the interpretation of the same evaluation results seems to vary between authors. The difficulties of evaluating problem-based learning programs, and particularly in comparing them with traditional programs at other institutions, are discussed in detail in Boud and Feletti (1997), part V. Again, the majority of the research relates to medicine, since that is the professional field where problem-based learning has been used for the longest period of time. Berkson (1993) from McGill University, which has a traditional medicine curriculum, in direct contrast to McMaster University, both Canadian institutions, has carried out a detailed literature review seeking evidence of the effectiveness of problem-based learning in medicine. He concluded that:

The graduate of PBL is not distinguishable from his traditional counterpart. The experience of PBL can be stressful for student and faculty...and implementation of PBL may be unrealistically costly...It is likely that over the next few years, PBL and traditional curricula will come to resemble each other. Current environmental and accreditation pressures, as well as pedagogical exigencies, will probably force traditional curricula to become better integrated and more interactive ... and practical realities will probably force PBL to become more faculty-structured. Even now there are reports of schools originally embracing orthodox PBL subsequently adding more structure to the curriculum. (pp. 57-8)

Yet, quoting many identical references, Bridges and Hallinger (1998) conclude that “compared with traditional programs in medical education, PBL programs generally yield equal or superior results” (p. 5). At least in the McGill vs. McMaster debate, the last word should probably go to Patel, Groen and Norman (1993) who represent both institutions and sit decidedly on the fence:

While much has been written regarding the potential benefits of problem-based learning, there is little empirical evidence regarding how the outcomes might differ from those of conventional curricula...In general, the differences in clinical competence were inconclusive. (p. 16)

Overall our research indicates that both curricula have their strengths and weaknesses. (p. 29)

There is, however, general agreement on the research relating to student perceptions of the problem-based learning environment that is summarized by Barrows (1996):

There are two meta-evaluations that have pooled the results of many PBL evaluations performed over the last twenty years (Albanese and Mitchell, 1993; Vernon and Blake, 1993). These studies indicate that PBL has done no harm in terms of conventional tests of knowledge and that students may show better clinical problem-solving skills. They also show that students are stimulated and motivated by PBL as a method. (p. 10)

Additional studies are discussed by Woodward (1997) which included the findings that students in PBL curricula report spending far less of their time engaged in rote learning without conceptual understanding. This has been supported by studies that have examined PBL vs. traditional timetables and find that PBL students have more time to engage in self-initiated learning activities (p. 296). Students' satisfaction with problem-based curricula and

their changes in approach to learning while undertaking the first year of four different programs in agriculture, architecture, medicine and paramedicine were examined by Feletti, Drinan, Trent and Maitland (1988). The authors concluded that students in all four programs were highly favourable towards the problem-based learning environments and that there was a small but statistically significant shift in their learning approaches from surface to deep learning during the year.

Within the engineering examples of problem-based learning discussed earlier, the evaluations that have been undertaken have been almost entirely along the lines of student interviews or responses to open-ended questions (e.g. Hadgraft, 1995). This qualitative research has generally found students in favour of the courses, where they have been sufficiently prepared for the problem-based environment (at McMaster and in some of the Monash courses). There have been positive program evaluations of the McMaster problem solving program in engineering (Woods et al., 1997), but “the role of PBL in attaining these outcomes could not be easily determined because the programs studied involved multifaceted skill development efforts.” (Woods, Felder, Rugarcia & Stice, 2000, p. 112) Unfortunately, in the engineering environment, qualitative research (and education research in general) is widely disregarded as valid support for anything, due to the traditional, scientific research culture (and limited background in educational theory) that exists amongst many engineering faculty. The limited extent of both the implementation and evaluation of problem-based learning in engineering also weighs against it as far as many faculty are concerned.

Considering a broader perspective of the question “does problem-based learning work in engineering?”, it is clear from the application of problem-based learning in engineering to date that there appear to be obstacles to its implementation across a whole engineering program. This issue may relate to the nature of engineering knowledge and practice compared with medicine, where problem-based learning has been widely adopted. Feletti (1993b) has touched on this issue when he described “another genre of professions [including engineering]...where problematic topics or situations loosely define the subject matter and where professional practice is typically not the process of solving well-defined problems.” (p. 146)

A very relevant and recent discussion on the suitability of problem-based learning has been published by Perrenet, Bouhuijs and Smits (2000) who conclude that “PBL has certain limitations, which make it less suitable as an overall strategy for engineering education.” (p. 345) Their discussion is based on consideration of whether PBL is possible, acceptable and optimal for engineering, and is framed around three educational objectives:

10. The acquisition of knowledge that can be retrieved and used in a professional setting.
11. The acquisition of skills to extend and improve one's own knowledge.
12. The acquisition of professional problem-solving skills.

Engineering has a complex knowledge structure, which can probably be most closely related to physics and mathematical knowledge, since they are at the base of much of the fundamental engineering science knowledge. Research into science and mathematics education uses constructivism as a referent for developing effective learning. (Treagust, Duit & Fraser, 1996) Constructivism is based on the premise that a student brings prior knowledge and conceptions (frequently mis-conceptions) to any learning situation. A new (scientifically or mathematically correct) conception will only be adopted by the student if he or she is firstly dissatisfied with the existing conception, and then also believes that the new conception is more intelligible, and plausible, and therefore superior to their existing conception. (Hewson, 1996) Thus, any teaching strategy with the goal of conceptual understanding in science or mathematics that fails to take student's existing conceptions into account is highly unlikely to be successful. Whilst a student may appear to have accepted the correct conceptions, and can pass traditional assessments in courses, the acid test is whether he or she will use those new concepts in applying knowledge to solve a problem outside of the experience of the course. This is the critical skill needed by engineers, since every problem encountered in practice will usually be different from those encountered previously in practice and almost certainly different from any encountered at university. However, Perrenet et al. (2000) report that "findings from research on misconceptions suggest that PBL may not always lead to constructing the 'right' knowledge." (p. 349) Hence it may or may not be useful for engineering education with regard to "the acquisition of knowledge that can be retrieved and used in a professional setting".

With regard to the second objective, Gijsselaers (1996) argues that metacognition is essential. He defines metacognition as a set of self-monitoring skills including "goal setting (What am I going to do?), strategy selection (How am I doing it?) and goal evaluation (Did it work?)" (p. 15) Skill in metacognition is essential for successful learning in PBL environments. However, this skill may not be enough in engineering due to the nature of the knowledge domain. In PBL, the order in which topics are learned is partly defined by the students themselves and hence some topics may be overlooked. Perrenet et al. (2000) describe the medical knowledge domain as having a "rather encyclopaedic structure, so the order in which various concepts are encountered is not prescribed and further learning will hardly be

affected by missing a topic” (p. 350), (in other words, if a topic is missed now, it can be filled in later). By contrast, mathematics, physics and much of engineering have a hierarchical knowledge structure. Many topics must be learned in a certain order, because missing essential parts will result in failure to learn later concepts. This problem will be hard for students to correct, no matter how good their metacognitive skills, because they probably can not fully compensate for missed topics as a result of using a PBL method. The issue of the particular hierarchical knowledge structure of much of engineering is possibly the most fundamental obstacle for implementation of problem-based engineering through an entire engineering program, as opposed to within individual courses in the program.

Professional problem-solving skills in engineering require the ability to reach a solution using data that is usually incomplete, whilst attempting to satisfy demands from clients, government and the general public that will usually be in conflict, minimising the impacts of any solution on the social and physical environment and doing all this for the least cost possible. Problem solutions may also extend over long time periods, for example, the design and construction of a new power station or development of a new manufacturing process may take several years. Problem-solving in medicine differs in that, however difficult it may be to make and despite the fact that opinions may differ, there will only be one diagnosis that proves to be correct, and at worst it may take a few weeks of tests to make, but usually be much quicker. Treatments after diagnosis may vary, but will generally be selected from a range of well-defined options. In addition, the only people who generally need to be satisfied are the patient, and possibly their family; governments and the general public are not of direct concern. According to Perrenet et al. (2000), a PBL approach is insufficient for the acquisition of professional problem-solving skills in engineering due to the usual time scale of the problems and the range of activities that they include.

One other issue is raised by Perrenet et al., (2000) that relates to the culture of the engineering profession. Engineering as a profession, including the engineering education sector remains a male-dominated, conservative, technically focussed culture, although some engineers (particularly the few women in the profession!) are working hard to change it. Hence the adoption of innovative educational methods may be difficult to implement in engineering, due to faculty resistance. Despite the fact that the medical profession could be similarly characterised (although not quite so male-dominated as it was), PBL has been readily adopted in medical education, probably because it “seems to mirror the professional behaviour of a physician more closely than the professional behaviour of an engineer.” (p. 352)

It seems therefore that problem-based learning may be a partial answer for resolving the critical issues of engineering education, primarily to demonstrate the application context in the early stages of an engineering curriculum. However, other active learning, student-centred methods may be more appropriate and acceptable for engineering education. In particular, an approach that more closely mirrors the professional behaviour of an engineer could be successful. This is the basis of project-based learning.

## **Project-based Learning**

The term *project* is universally used in engineering practice as a unit of work, usually defined on the basis of the client. Almost every task undertaken in professional practice by an engineer will be in relation to a project with varying time scales. A project such as the construction of a large dam or power station may take several years, whilst other engineers may be involved on numerous small projects for various clients at any given time. Projects have varying complexity, but all relate in some way to the fundamental theories and techniques of an engineer's discipline specialisation. Small projects may involve only one area of engineering specialisation, but larger projects will be multi-disciplinary, not only involving engineers from different specialisations, but other professional and non-professional personnel and teams. It is expected that an engineer will progress during their career from involvement in the technical aspects of small projects or small components of large projects under supervision after graduation, to the eventual management of large projects with a correspondingly limited personal involvement in the technical design components.

Successful completion of projects in practice requires the integration of all areas of an engineer's undergraduate training. In response to the issues of engineering education discussed previously, it is proposed by many in industry that projects should therefore be a major component of student learning during that training, hence the term *project-based learning*. Projects should gradually increase in complexity over the duration of the program, with technical as well as communication, teamwork and managerial skills being introduced and then revisited through successive projects. Ideally projects should integrate all technical specialisations within a particular engineering field as well as other professional areas through the use of multidisciplinary teams (e.g., architects, builders, civil engineers, environmental scientists, economists). However, if this is not feasible at a particular institution, individual lecturers or specialisation teams can still implement project-based learning within their own courses.



Project-based learning may be defined in various ways by different educational disciplines and levels. Projects are frequently used in K-12 education, so it is a concept and teaching method that is familiar to most university entry students. The K-12 use of projects is usually traced back to Dewey in the early 1900's (e.g. Dewey, 1902) and Kilpatrick in the 1920's (Kilpatrick, 1925) in the United States of America and has been described by Blumenfield et al. (1998), who define it as follows:

Project-based learning is a comprehensive perspective focused on teaching by engaging students in investigation. Within this framework, students pursue solutions to nontrivial problems by asking and refining questions, debating ideas, making predictions, designing plans or experiments, collecting and analyzing data, drawing conclusions, communicating their ideas and findings to others, asking new questions, and creating artifacts. (p. 81)

These authors state that there are two essential components of projects: A question or problem that organises and drives the project, and a series of artifacts or products culminating in a final product that resolves the question. Whilst teachers may set the question and direct some of the activity, it is also possible for students to be responsible for creating both the question and activities. Polman (2000) details a recent case study illustrating the latter approach in a high school earth science class. In either case, the outcomes are not pre-determined and hence students are able to develop their own approaches to resolving the question. Blumenfield et al. (1998) summarise several key outcomes of project-based learning (p. 81):

- As students investigate and seek resolutions to problems, they acquire an understanding of key principles and concepts.
- Students are placed in realistic, contextualized problem-solving environments.
- Projects can serve to build bridges between phenomena in the classroom and real-life experiences.
- Projects help students to learn that problems may be solved through systematic enquiry.
- Projects require active engagement of students' efforts over an extended period of time.
- Projects promote links between subject matter.
- Projects are adaptable to different types of learners and learning situations.

Although these learning outcomes relate to K-12 education, it is easy to see that the use of projects could be extended to university level, where the knowledge base developed, integration achieved and problem-solving skills developed could be focussed on a particular profession, such as engineering. It is also obvious that many of the outcomes are not dissimilar to learning outcomes claimed for problem-based learning.

### **Project-based learning and problem-based learning – similarities and differences**

A comparison of problem-based and project-based learning at tertiary level was made by Perrenet et al. (2000). They noted that the similarities between the two strategies are that they are both based on self-direction and collaboration, and that they both have a multi-disciplinary orientation. The differences that they noted included (p. 348):

- Project tasks are closer to professional reality and therefore take a longer period of time than problem-based learning problems (which may extend over only a single session, a week or a few weeks).
- Project work is more directed to the *application* of knowledge, whereas problem-based learning is more directed to the *acquisition* of knowledge.
- Project-based learning is usually accompanied by subject courses (e.g. mathematics, physics, etc. in engineering), whereas problem-based learning is not.
- Management of time and resources by the students as well as task and role differentiation is very important in project-based learning.
- Self-direction is stronger in project work, compared with problem-based learning, since the learning process is less directed by the problem.

However, these differences were noted for problem-based learning compared with project-based learning in medicine, and hence they may not all hold for engineering. In particular, in engineering, subject courses are still widely used with problem-based learning.

The similarities and differences between problem-based and project-based learning have also been discussed by De Graaff (1993b). He notes that both methods “employ problems in the integration of theory and practice, both enhance small group work and both support self-directed learning.” (p. 33) However, the fundamental difference is in the use of problems. In problem-based learning, the problem is used as a basis to start the learning process, and the solution of the problem is not the issue. By contrast, in project-based learning, the problems are real life problems (possibly simplified depending on the level of the students), and the

solution of the problem is a fundamental requirement. Hence, for engineering, using projects to teach corresponds more closely to actual practice than problem-based learning. This view is affirmed and expanded by Van Woerden (1993) who explains that the problems in problem-based learning are often constructed using the “concepts derived from the theory as the real starting points of the instruction process.” (p. 42) Hence the problems are either chosen or constructed to “serve as the best illustration of the theory.” (p. 42) In project-based learning, one of the objectives of a project is to identify the relevant problem(s) and define them, hence finding the best, practical solution of the problems is the objective of a project.

### **Variations of project-based learning**

The previous examination of problem-based learning within this chapter showed that although the pure version was applied throughout a curriculum, many variations existed, and in engineering it was more usual to apply problem-based learning within individual courses. These same variations apply to the use of project-based learning and are described by Heitmann (1996), who differentiates between “project-oriented studies” and “project-organised curriculum.” (p. 127) According to Heitmann, project-oriented study involves the use of small projects within individual courses, progressing to a final year project course. The projects are usually combined with traditional teaching methods within the same course, focusing on the application, and possibly the integration of previously acquired knowledge. Projects may be carried out as individuals or in small groups. (From personal experience in both learning and teaching in engineering programs that utilised this approach, the author would argue that the assumption that the knowledge has been previously acquired through the traditional lecture courses is questionable. The author’s own experience and what she has seen repeatedly in the case of students who undertake project work that the author teaches, is that the knowledge may have been *seen* in the lectures, but it is not *acquired* or integrated with students’ previous knowledge until it is applied in project work).

Project-organised curricula use projects as the structuring principle of the entire curriculum, with subject-oriented courses eliminated or reduced to a minimum and related to a certain project. Students work in small groups with a project team of teachers who are advisers and consultants. Projects are undertaken throughout the length of the course and vary in duration from a few weeks up to a whole year (Heitmann, 1996). In reality in engineering, a completely project-organised curricula does not yet exist, and the closest are programs where projects and project-related courses make up 75% of the program, as at Aalborg University in Denmark, which will be examined in more detail below.

Anette Kolmos, a faculty member at Aalborg University in Denmark, which has used project-organised curricula since the early 1970's, has defined project work slightly differently from Heitmann. At the outset she points out that "What one institution practises as problem-based learning may look very much like what another institution practices as project work." (Kolmos, 1996, p. 141) However, she argues that the "ideas of problem-based learning and project work support each other and emphasize different aspects of learning" (p. 141) and that the main idea of both is to emphasise learning instead of teaching. This definition points to the ambiguity of the two terms as far as engineering is concerned, but from the literature reviewed in the previous section, and the definitions provided in this section of the review, it is clear that most of what engineering programs have termed as problem-based learning in individual courses is better considered as project-based learning.

Kolmos' defines project work as:

... a way of organizing the learning process... characterized by an active discussion and writing process in a group-based course. Project work stresses both the process and the product in the form of a project report...teamwork is an integrated concept of project work. (p. 146)

The argument about whether project work is teacher-centred or student-centred requires further discussion. Kolmos (1996) makes the point that there may be different types of project offered in the same engineering program that vary in the degree of teacher and student direction of learning. She proposes that three types of project work exist in the Aalborg program, but that all have the common characteristic that a problem has to be analyzed and solved by means of different kinds of methods. They also have the same phases of preparation, problem analysis, demarcation, problem solving, conclusion and reporting. (p. 142) The difference between the project types is the extent of teacher control or student direction.

- Assignment projects involve considerable planning and control by the teachers. The problem and the subject, as well as the methods are chosen beforehand. These projects are the most similar to those already found in many traditional engineering programs.
- Subject projects where the students have a free choice "either of problem within the subject" or the problem will be given and the students have a "free choice among a number of described methods." (p. 143)
- Problem projects that are based on the problem as the starting point. Students have to "start with a problem, analyze it, find fundamental solutions to the

problem, choose the right solution and outline strategies for implementation.” (p. 143)

The three types of projects deal with different objectives and lead to different knowledge and skills, and Kolmos argues that “all three types of projects are necessary in order to secure the quality of competencies achieved in the education.” (p. 144) The problem projects will be most like problem-based learning with regard to student direction of learning and the role of the teacher. However, Kolmos differentiates between the teaching roles as a “process-oriented supervisor” (p. 147) in problem-based learning compared with a “product-oriented supervisor” in project-based learning. (p. 147)

### **Project-based learning in engineering**

There are several examples of project-based learning being used in courses in engineering programs that have been reported in the literature. Some of them use the term project-based, others use the term problem-based learning, but are actually project-based learning in accordance with the definitions discussed earlier. Still others use the terms interchangeably, which points to the grey area that exists in engineering between these terms. The courses reported cover a range of discipline areas and program levels. Examples include:

- A graduate level course in the Department of Civil and Environmental Engineering at Worcester Polytechnic Institute (USA) entitled Integration of Design and Construction. (Albano & Salazar, 1998).
- Final semester undergraduate industry projects in all disciplines at the Engineering College at Hogskolen i Telemark, Norway (Clausen, 1998).
- Third or fourth year undergraduate courses in hydrology at Adelaide and Monash Universities, Australia. (Daniell & Hadgraft, 1993).
- A planned integration of practical industry-based design projects in eight courses spread over the four years of the Civil Engineering program at NJIT Newark College of Engineering, USA. (Davis, 1998).
- A fourth year Chemical Engineering course on advanced heat transfer at RMIT, Australia (Inglis & Ball, 1992).
- The Sooner City project across the four years of the undergraduate program in Civil Engineering at the University of Oklahoma, USA. (Kolar et al., 2000).
- First and second year courses in engineering mechanics and steel structures at Queensland University of Technology (Mahendran, 1995) and in structural

mechanics in second year at the University of South Australia. (Mills, Zhuge, Rajakaruna & Mills, 1999).

- Projects in the EPICS courses in first and second year at the Colorado School of Mines, USA. (Pavelich, Olds & Miller, 1995).
- Several US examples cited in Rosenbaum (1996) including Rose-Hulman Institute of Technology, Carnegie Mellon and Worcester Polytechnic Institute.
- The use of a theme project to integrate related courses at various stages of the Civil Engineering curriculum at Pennsylvania State University, USA. (Scanlon, Hiltunen & Marra, 1999).
- A first year Electronic Engineering design course at La Trobe University, Australia (Whittington, 1997).

The number of engineering schools that have programs that approach Heitmann's definition of a predominantly project-organised curriculum is considerably less. Heitmann (1996) cites several European examples: Aalborg and Roskilde in Denmark; Bremen, TU Berlin, Dortmund and Oldenburg in Germany; Delft and Wageningen in the Netherlands. (p. 124) More detail of the Industrial Design Engineering program at Delft is provided by Marinissen and De Graaff (1994). The programs at Aalborg in Denmark, Monash University and Central Queensland University in Australia are described in more detail below.

### Aalborg University

The project-centred engineering program at Aalborg University has been described by several authors throughout its development. The details for the following description are summarised from Fink (1999), Luxhoj & Hansen (1996), Kjersdam (1994), Ostergaard (1989), Fruensgaard (1989), and Creese (1987).

Aalborg University, formed in 1974 by the merger of five different education institutions, has three faculties - Arts and Languages, Social Science, and Technology and Science. There are approximately 10000 students at the university, of whom about 4000 are engineering students. The Faculty of Technology and Science includes 530 faculty, 130 PhD students and 150 other staff (Luxhoj & Hansen, 1996, p. 184). The degrees offered are a three-year Bachelor degree, or a five-year Master Degree. Approximately 90% of students choose to complete the Master degree. The discipline areas offered include mechanical, industrial, manufacturing, civil, electrical and electronic engineering.

From the founding of the university, all of the programs, including arts and social science as well as engineering, have used project work as the key element. All engineering programs undertake a common, first year basic studies program in mathematics, physics and computer science, which is taught primarily in a traditional format. This first year also includes an introduction to the methods of project work and teamwork that the students will need for the rest of their program. In the remaining two or four years, the curriculum consists of 50% project work, 25% course work (i.e., lectures, seminars, laboratory exercises) that support the project work, and the remaining 25% coursework in fundamental studies such as mathematics and physics. Project-based teaching is strongly problem-oriented, and the projects are often practical industry problems, with new problems assigned to groups each year. Students work in groups of five to seven for the project work and each student group has assigned office space. New groups are formed each semester, but since students choose their group members, some stay in the same group for several projects. Students choose a project from a list that the faculty has approved and all of a given semester's projects have a common theme of study.

Each project group is assigned two faculty advisers, one of whom is an assistant. Faculty members supervise three to five project groups as well as teach coursework in their specialty area. If the projects deal with topics that are new to the faculty, the teaching staff are expected to study them to be able to be on equal terms with the student group. There may also be a need for the faculty member to assist with interpersonal problems in the group. The demands on faculty are broader than those in a traditional university environment and it has been acknowledged that not all of the original faculty were able to adapt to the challenges. (Fruensgaard, 1989, p. 25) However, the number of faculty fully supporting the program is increasing.

The semesters at Aalborg are 20 weeks long, with two semesters each year. This is allocated in three six-week segments, plus two weeks for project evaluation at the end. In the first six weeks the emphasis is on coursework required for the project and the final six weeks are fully devoted to project completion. In the final semester before graduation, a comprehensive project or thesis is carried out in groups of no more than three. The final projects receive a score of 0 to 13, but all other projects are given only a pass/fail grade. The final submission of projects requires a report of 80-180 pages as well as a group oral presentation to the examiners, and any individual in the group may be examined on any aspect of the project. Assessment is conducted by a project evaluation committee, which always includes the two faculty advisers for the group, but also involves an external examiner from industry or academia in the second, fifth and final semesters.

Several evaluations of the Aalborg University project-based engineering program have been carried out. Some of these are described in detail in Fink (1999) and Kjersdam (1994). The university itself has established an internal quality assurance program, which involves student and faculty evaluation of every course and project each semester. These results are discussed by the Study Board (consisting of five professors and five students) who can make changes such as replacing a professor in a project if necessary (Fink, 1999, p. 4). The electronic and electrical engineering programs at both Aalborg University and the Danish Technological University (with a traditional program) were evaluated by an international committee in 1998. Earlier evaluations also occurred in 1993 and 1989.

The 1998 evaluation used self-evaluation reports from each institution, a questionnaire to graduates of each school and interviews with representatives from industry leaders, as well as a site visit to each school. Reminiscent of the McMaster vs. McGill evaluations, the findings were that both programs were excellent but that the graduates focussed on different skills. Aalborg graduates were stronger in team skills, communication, ability to carry out a total project and generally more adaptable and thus, more directly employable on graduation. DTU graduates were stronger in engineering fundamentals and more capable of independent work, but generally required more on-the-job training. The Aalborg graduates themselves, three to four years after graduation, expressed quite strongly that they felt they had been well prepared for the profession and better prepared than those from the traditional program. They also felt that the weight of project work in the program was sufficient and that the project work was the main source of their professional knowledge, as well as where they had learned to apply it. This evaluation by the Aalborg program graduates is one of the few reported in the literature that relates to the second research question of this study, regarding the perception of the students themselves of the relevance of project-based learning to their professional practice, although the Aalborg study is not specific to the field of structural engineering.

Differences in the retention rates and completion times between Aalborg and DTU have been noted. The Aalborg dropout rate is 20-25% and most occurs in the first year. In the traditionally taught Danish programs the dropout rate is approximately 40%. (Creese, 1987, p. 104) Approximately 80% of Aalborg students complete their degree requirements in the minimum time. (Luxhoj & Hansen, 1996, p. 185)

### Monash University

As discussed previously, Monash University has implemented problem-based learning in several courses within its civil engineering program and has speculated on what a problem-



based curriculum might look like. (Hadgraft, 1993) In 1996/7 the civil engineering department made a commitment to introduce project-based and problem-based learning throughout its program. The new curriculum has been phased in from 1998 (first year) to 2001 (fourth year). The key reasons stated for the implementation of the new program were that it utilised a constructivist approach to learning and acknowledged a range of learning styles; it incorporated many of the recommendations of the Review of Engineering Education conducted in Australia in 1996; and it used the findings from the previous trials with problem-based learning at Monash that found that students engage more effectively with this style of learning (Hadgraft, 1998, p. 15).

In the same way that Kolmos (1996) distinguished between assignment, subject and problem projects and described the Aalborg program as progressing through each stage, Monash has used the terms project-assisted learning, project-based learning and problem-based learning to describe the stages through which its students progress during the program (Hadgraft & Young, 1998). The definitions they have adopted are shown in Table 3.3.

**Table 3.3 – Definitions of stages of project/problem-based learning in Monash University Civil Engineering program (Hadgraft & Young, 1998)**

<b>Stage Name</b>	<b>Description of Activity</b>
Project-assisted learning	Project and exercises. The teacher delivers and controls the content.
Project-based learning	The project is the dominant activity. Students access content when required, but the teacher prepares much of it.
Problem-based learning	Students control the content, delivery and interaction (in groups) while the teacher usually determines the project/problem.

In the first year of the course, the emphasis is on project-assisted learning, i.e., collaborative, group-based projects, but this is only in the one Civil Engineering course. The remainder of the program in first year involves generic skill development courses, common to all engineering programs, in mathematics, computing, physics, etc.

The second year of the program still includes some generic skill courses, but a significant proportion of the courses are civil engineering based. These courses continue to use project-assisted learning, but with increasing emphasis on the students finding the information they require. In third year, student project groups access course content in their own time and place but faculty are still responsible for the key course resources. Project-based learning is the model at third year level.

In the final year of the program, (implemented in 2001) students are expected to operate with significant autonomy in terms of setting projects and finding resources. Student groups are expected to identify their learning needs and find learning resources, thus this stage incorporates problem-based learning. In some courses, students will work on projects as individuals and for others in groups. The final year also allows students choices of electives both within civil engineering specialisations as well as inter-faculty electives and free choice electives outside of engineering.

As the program is only just reaching full implementation, evaluations to date have focussed on student interviews and questionnaires. However, it is clear from examining course documentation as it currently exists on the website for the program that many of the courses have retained some lecture format combined with the projects. The project-based component of assessment in the majority of courses is from 40% to 60%, with the remainder being a traditional examination assessment.

### Central Queensland University

Central Queensland University (CQU) introduced a project-based engineering degree in 1998. (Wolfs, Howard, Vann & Edwards, 1997a; 1997b; Wolfs, Howard, Vann & Boyd 1998) CQU offers engineering degrees in the specialisation areas of civil, electrical, mechanical and computer systems engineering, all of which have adopted a project-based model, with 50% of the students' workload in each semester allocated to a project-based unit. Each semester consists of two six-credit point units, used to develop the theoretical knowledge bases, and a 12-credit point project-based unit. The projects gradually increase in length and difficulty throughout the program. An added difference in the CQU program is that it is a co-operative format, where students undertake two semesters of a total of nine semesters in a full-time industrial work placement.

The co-operative program attracts high quality students, but in common with all other engineering programs, attrition and motivation problems occurred in the first year of the previous program. For that reason CQU decided against the Aalborg model of a basic foundation year and introduced project-based courses as 50% of first year as well. These first year courses focus on developing skills in team-work, communication, computing, problem-solving and others, as well as introducing students to engineering issues such as ethics, environmental and social factors.

Initial indications are that retention rates have improved along with student grades. Program assessments have again been focussed on student evaluations. The program has been reviewed by the faculty against the revised Institution of Engineers, Australia accreditation

guidelines (IE Aust, 1999), and they believe it will have demonstrably better outcomes against the revised guidelines compared to the previous program. The program received full accreditation from the IE Aust in September, 2001.

### **Is project-based learning successful in engineering?**

The difficulty in assessing the success of project-based curricula in engineering is the same as for the problem-based learning programs in medicine. What criteria are appropriate? A comparison between project-based outcomes and traditional curriculum outcomes is not comparing apples with apples. This is summarised by Heitmann (1996):

All too often the success and effectiveness of project orientation is measured against the cognitive and knowledge orientation of the traditional subject learning. This is not appropriate with respect to the described aims of project work. Trust in self-determined student learning effects is necessary as well as the development of suitable assessment procedures which do not focus on product and content mainly, but equally on skills and attitudes. (p. 129)

He suggests that methods, which have been developed from knowledge gained in the last 20 years of European experience, should be adopted, including permanent review of processes, self-assessment by students, and involvement of external examiners. Hence, when considering the fourth research question of this study – *How effectively do engineering students achieve the intended learning outcomes using a project-based approach?* – it is likely that a variety of methods of assessment will need to be used.

An interesting demonstration of Heitmann's point is given by Lenschow (1998) in describing the outcome of a structural engineering course with 30 students that was split into two parts. One group undertook a traditional curriculum, while the other half formed PBL groups and had no lectures. Each half was asked to design a concrete car park building. The traditionally taught group:

...became expert in accurate calculation of load capacity of slabs of a building, how reinforcement should be bent and placed in concrete, etc. The PBL class was most concerned with the function of the building ... traffic flow and optimum use of the slab area. It was less important to save 20 mm in slab thickness, while this might be a major point for the traditional class. Hence according to traditional teaching the first class acquired correct knowledge and more competence than the PBL students, while some teachers, owners and users in the market-place saw a substantial added value in the teamwork, leading to a holistic approach and solution. The two classes could not have the same exam, so a direct comparison was impossible. (p. 160)

Apart from Aalborg and some other European examples, the use of project-based learning as a major part of the curriculum is new to engineering, whilst the use of the assignment projects or project assisted learning is long-standing but poorly evaluated. The most appropriate answer to this question is probably the same as that to the question of problem-based learning's effectiveness in medicine – It depends what you want! From the limited evaluations to date, the findings are similar to those of PBL in medicine. Students who participate in project-based learning are generally motivated by it and demonstrate better teamwork and communication skills. They have a better understanding of the application of their knowledge in practice and the complexities of other issues involved in professional practice. However, they may have a less rigorous understanding of engineering fundamentals.

Specific evaluations relating to the third research question of this study, i.e. students' perception of the relevance of project-based learning to the professional practice of structural engineering, were not located in the literature. In the courses cited previously as examples of the use of project-based learning in engineering, evaluations either did not consider students' perceptions, or did not consider their perceptions related to professional practice. Aalborg University has surveyed past graduates (not specifically from structural engineering) after three to four years of graduate experience about whether the project-centred education provided the necessary knowledge and experience for professional practice. A total of 339 survey responses were received (74% of the sample). Approximately half of those surveyed considered that project work they had undertaken during their study was the main source of their professional knowledge, while one-fifth stated that their main source was from colleagues. The majority of respondents also felt that they had been well prepared for professional practice. The only exception to this were that 30% of the civil and structural engineers surveyed had felt a lack of practical experience in their first employment. (Kjersdam, 1994). Whether there were differences in that program compared with the other

program areas at Aalborg is not discussed. However, these results do give some support to the hypothesis that students do perceive that project-based learning is relevant to professional practice.

## **Summary**

In the context of the requirements of revised accreditation criteria and the calls from industry on what they need from graduates, it would appear that project-based learning is more likely to satisfy these demands than traditional curricula. It also has been demonstrated that the engineering profession and academics are familiar with the concepts of projects in their professional practice. It therefore seems that project-based learning is likely to be more readily adopted and adapted by university engineering programs than problem-based learning. Its use should be promulgated as widely as possible, because it is certainly clear that any improvement to the existing lecture-centric programs that dominate engineering would be welcomed by students, industry and accreditors alike.

# Chapter 4: The study methodology

## **Introduction**

This chapter presents details of the methodology of the case study that was undertaken. The background of the civil engineering program at the University of South Australia, the particular course used in the case study and the students who undertook the course are examined. The curriculum framework used for the research is detailed in relation to the case study and the multiple data sources used for the study are examined. A discussion of issues related to the reliability and transferability of the data concludes the chapter.

## **The Case Study – Building for People N**

The case study undertaken for this research project involved a structural engineering course titled *Building for People N*, taught by the researcher at the University of South Australia in the first semester (March to June) of 2001. The following discussion examines the context of the course in this case study with regard to the overall civil engineering program, the student cohort and the data sources used.

## **The civil engineering program at the University of South Australia**

Civil engineering at the University of South Australia is available as a four-year undergraduate degree, Bachelor of Engineering (Civil and Water Engineering). The University of South Australia became a university in 1991, but civil engineering had been taught at its antecedent institutions, the South Australian Institute of Technology and the South Australian School of Mines since 1931. The degree is recognised as being industry focused, and the majority of its graduates find work in the construction industry, although a considerable number also enter the design field. All undergraduate engineering degrees in Australia are of four years duration, with two semesters each year, each semester usually consisting of 13 teaching weeks plus examinations. Students entering the first year are assumed to have studied Mathematics 1 and 2 (which includes calculus) and Physics at Year 12 level. If they have not done Mathematics 2 and/or Physics, then a bridging program is available during the first year and the summer before second year to provide a bridge to gain this knowledge.

The first year of the degree involves courses in science, mathematics (2), communication, technical drawing, engineering materials, workshop practice and innovation and engineering

mechanics. Several of these courses involve small projects carried out by pairs or small groups of students. The projects at this first stage of the program, if classified according to Kolmos' system (Kolmos, 1996, p. 143) are predominantly assignment projects, although the project in the innovation course is closer to a problem project where students in groups of four are set a reasonably abstract problem based on physics fundamentals and are required to design and build a device to solve it, then test their solution in a class competition. Two courses within first year – engineering materials and engineering mechanics – provide some foundation technical knowledge necessary for later study in structural engineering, with technical drawing and communication courses assisting with necessary generic skills.

The course of most relevance to the area of structural engineering in the second year of the program is *Mechanics and Structures*. The content includes basic structural analysis and strength of materials topics, and is taught through traditional lectures and tutorials, peer-assisted tutorials, a study guide and a series of four small projects carried out in pairs or groups. One of these projects would be classified as a subject project and the remainder as assignment projects. The details of this course have been discussed in Mills et al. (1999). Apart from this course, there is little project work conducted in the other second year courses of the degree program.

The first and second courses in a total of three specialist structural engineering courses in the degree program are taught in the third year, including *Building for People N*. All of the structural engineering courses use a combination of lectures, tutorials and projects in their delivery. Other courses in the third year of the degree also involve project work in the areas of water engineering, computer analysis methods and professional practice. On average across the third year courses of the degree, projects contribute approximately 30% of the overall assessment, which could be considered to fit with Heitmann's definition of project-oriented study. (Heitmann, 1996, p. 127)

During the final year of the civil engineering degree, students undertake two major projects that account for 50% of the courses during the year. One of the projects is conducted in pairs and is a research project in the student's main area of interest of the four specializations within civil engineering, either structures, water, geotechnics or transport systems. This research project extends for the full year. The other project is a design project undertaken by the class as a whole, which forms 50% of the final semester course load. Both the research and design project courses definitely fit Kolmos' classification of problem projects (Kolmos, 1996, p. 143), where students are expected to use knowledge they have gained during the previous three years as well as seek out any further knowledge they require to find a solution

to the problem. The problems are outlined only in basic form by the lecturers, and no solution is pre-determined or known by the lecturers themselves.

The final year research and design projects have formed part of the civil engineering degree program at the University of South Australia for many years, but in recent years they have become more open-ended in their structure. Assignment type projects had also been used in other courses for several years, but their use, and particularly the proportion of assessment accorded to them has increased markedly in recent years. The increased use of projects within the civil engineering program over recent years has primarily been due to the retirement of older faculty, who were more comfortable with traditional lecture-based courses, and the influence of newer faculty members who support project-based learning. However, although the faculty believe in the value of projects as learning tools and students support the use of projects in the informal evaluations that have been conducted, this is based on anecdotal evidence and there has been no previous attempt within the school to evaluate projects in a rigorous manner, as is done in this case study.

### **The course – Building for People N**

*Building for People N* is taught in the first semester of the third year of the civil engineering degree program. The course introduces students to the analysis and design of structures in steel and reinforced concrete: it is the first exposure of the students to real structural engineering. The course as taught for the case study involved an average of five contact hours per week over 13 weeks, consisting of approximately two hours of lectures, 1.5 hours of tutorials or practicals and 1.5 hours of design project sessions. The exact nature of the contact hours varied over the semester, for example more lectures were used when a new topic was introduced, with more project sessions at other times. In addition, during the case study some additional changes were required to be made to the original timetable due to personal circumstances. Assessment was based on 50% examination, 40% for two design projects and 10% for practicals. The class schedule and assessment details were included in the Course Handout given to students during the first lesson (and posted on the course webpage). The Course Handout has been included as Appendix B1.

### **The projects**

The course involved two streams of structural engineering - the design of steel structures and the design of reinforced concrete structures. The first six weeks of the course were devoted to lectures, tutorials and a design project in steel structures and the remaining seven weeks to reinforced concrete structures.

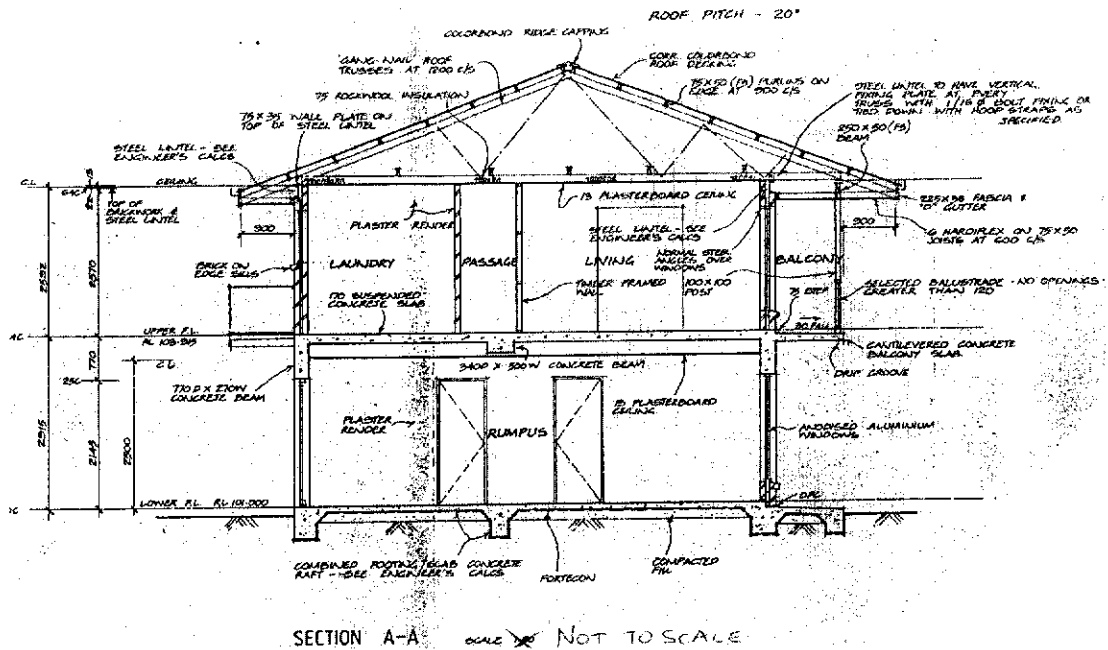


The steel design project was a single storey industrial building, braced in two directions for wind loading. Although a building of this size would normally be constructed using a portal frame in practice, as this would be a more economical and practical solution because it would eliminate the need for central columns, the students in this course did not yet have the theoretical background of rigid frame analysis that a portal frame structure would require. (The same student cohort undertook a portal frame design project in the following semester as part of the subsequent structural engineering course). In addition, a two-way braced structure meant that the beams and columns could be assumed pin-ended, making the member analysis fairly simple and thus enabling the member design to be the primary focus of the project. The project handout, including plan and elevation drawings, is included as Appendix B2.

The stages usually involved in the design of a steel framed industrial building in practice could be summarised as: determination of building layout and dimensions, selection of the structural system, determination of loads, analysis of the structure, design of the structural elements, and documentation of the design through drawings and calculations. Of these stages, the first would usually be carried out by an architect and the remainder by a structural engineer. For the project used in this course, the selection of the structural system (i.e. two-way braced) was made by the lecturer to ensure that the analysis and design could be carried out by the students using the knowledge base they developed through the course. However, all of the other stages of design were included within the student project and in all cases this was the first exposure of the students to these tasks. In a traditional lecture-based course on steel design, the design of the structural elements would be the only one of these tasks that would be taught.

To assist students in getting started on the project and give them an indication of the order in which these tasks would be approached by a professional structural engineer, the project handout included a detailed list of items that were required to be completed in the project. Marks were allocated to each item on the list and an estimated completion date for item groups was also given. The detailed mark allocation was used to measure the achieved curriculum for the students, as discussed later in this chapter. However, the mark allocation and completion dates also gave students an indication of the relative complexity of the various tasks and the amount of time they should spend on each. Students were not asked to design every element of the building, as would be necessary in practice, and students working alone were able to omit some design tasks. In summary, students were asked to determine the loads on the overall building and individual elements, design two beams, two columns and one connection, and to document their design through drawings and calculations.

The reinforced concrete design project was based on an actual two-storey house and students were provided with copies of the architectural drawings for the house. Several simplifying assumptions were specified in the project handout, both to limit the structural analysis involved to a level for which the students had sufficient theoretical background, and to ensure that the work could reasonably be completed in the available timeframe. The reinforced concrete design project handout is included as Appendix B3, excluding the architectural drawings, and a cross-section of the building is shown in Figure 4.1 (picture quality is poor due to photocopy reproduction of dyeline drawing prints).



**Figure 4.1 – Architectural cross-section of the two-storey house used for the reinforced concrete design project.**

Students were again provided with a detailed list of design tasks required, with mark allocations and estimated completion times. The same design stages of load determination, structural analysis, element design and documentation through calculations and drawings were required in the concrete project as for the steel project. In the reinforced concrete project students were asked to design two floor slab panels, two beams and two columns. However, the structural analysis and load determination for the reinforced concrete project was more complex than for the steel project because continuous slabs and beams were involved rather than pin-ended beams. In addition the project required students to develop an understanding of architectural drawings, which most had not previously encountered. Hence the project offered the students the opportunity to extend the initial understanding of the structural design process that they developed in the steel project.

## **The students**

The original enrolment in the course was 23 students. One student did not attend any classes and subsequently withdrew without submitting any work, so was discounted from the study. A second student completed the first design project and subsequently withdrew from the course without submitting further work, completing a student journal, sitting the examination or completing the questionnaires. This student worked in a pair on the first project, so his results are reflected in the marks of his partner in the first project, but he was also discounted from the study. A third student submitted the first project, attended classes all semester and completed the questionnaires, but did not submit the second project, a journal or sit the examination. Since the questionnaires were completed anonymously, his responses could not be excluded from their analysis, but his results have been excluded from the achieved curriculum analysis since he submitted only 20% of the course requirements. Hence the class size used for the full study was 21 students for the perceived curriculum analysis and 20 students for the achieved curriculum analysis.

Civil engineering students at the University of South Australia generally come from a variety of backgrounds. The majority are school leavers who enrol in the civil engineering degree after the completion of Year 12 of high school. However, a significant number in each cohort, including the study cohort, come from other backgrounds. These include mature age students who have worked in other industries, or have worked at a technician level in civil engineering and are now completing their degree, and overseas students who have usually completed a civil engineering diploma in their own country. (There are several different criteria used by the university to define mature age or alternative entry students, but generally they will be people who have left high school at least three years before applying for entry to the University). Civil engineering is also available as a double degree with other undergraduate degrees. Of the 21 students in the case study, 15 students were enrolled in the Bachelor of Engineering (Civil) degree program, three students were enrolled in a double degree of BE (Civil) with a Bachelor of Applied Science in Environmental Management, and three students were enrolled in a double degree of BE (Civil) with a Bachelor of Arts (International Studies). Engineering continues to be a male dominated area of study, with the average percentage of women enrolled in engineering programs in Australia being 14.8%. (National Centre for Gender & Cultural Diversity, 2000) However, the student cohort in the study consisted of five women and 16 men, or 23.8% women, which was above the national average, but typical of the civil engineering cohorts at the University of South Australia at present. The students also came from diverse cultural backgrounds, with one third of the class speaking a language other than English at home, although all but three were

born in Australia. The characteristics of the student cohort in this study are given in Table 4.1 below.

**Table 4.1 – Characteristics of the student cohort in the case study**

<b>Student background</b>	<b>No. of students</b>	<b>% of students</b>
School leaver – enrolled in the degree directly after completion of Year 12	12	57
Mature age student with civil engineering diploma and relevant work experience	4	19
Mature age student with other work experience outside of civil engineering	3	14
Overseas student with civil engineering diploma from their home country	2	10
Total students	21	100

The previous academic record of the student cohort in the study was mixed. Of the school leaver group of 12 students, only four had progressed through the degree program in the minimum number of years (i.e., without failing a sufficient number of courses that required them to repeat a year or part of a year). Of the mature age students, only two had taken an additional year, the rest had progressed in the minimum time, and one of the overseas students had repeated a year. However, it should be noted that it is very common in engineering programs for an additional year to be required to complete the degree due to the difficulty of the courses. The better performance of the mature age students compared with the school leaver students is also typical, usually due to higher motivation and greater maturity, as well as relevant background knowledge in the case of those with civil engineering technician experience. Hence the previous academic records of the student cohort in the study group were considered by the researcher to be from a normal range.

Design projects were generally undertaken in pairs, although some students elected to work individually. Students were free to select their partners for each project. Many remained in the same pair for the whole course, but some changed partners or chose to work individually after the first project. In the first project, 20 students worked in pairs and the two overseas students worked individually (as mentioned earlier, one student subsequently withdrew from the course leaving 21 students). In the second project, 12 students worked in the same pairs, four worked in different pairs and five worked individually. The increase in number of students working individually in the second project was for a variety of reasons. One student was away for part of the time representing the state in rugby, so he elected to work individually as he felt it would not be fair on a partner to be away. His previous partner also

elected to work individually because he felt that he had not contributed, and consequently had not learnt as much as he should have from the first project, so wanted to work on his own in the second. Another pair of students did not work together in the second project, because one was having personal difficulties that prevented her from attending class as much as she should have, so she decided she would work alone.

The two overseas students in the course came from very different backgrounds. One was a mature-age male from Fiji who had a very poor academic record, combined with a non-communicative personality and consequently no one in the class wanted to work with him. He subsequently failed the first project and did not submit the second project or sit the examination, and was actually precluded from the university at the end of the semester due to his continuing poor academic record. This student presented somewhat of a dilemma for the author as both a lecturer and researcher in this study. The student believed that he was being discriminated against by being required to work on his own and stated this in his Course Evaluation Questionnaire (although they were anonymous, his writing and grammatical style, as well as the content of the response made his form readily identifiable). However, it was pointed out to him that students working alone were given a reduced scope of work in the project to compensate for this, as detailed in the project handout. He was also offered the opportunity of access to the lecturer at any time for additional assistance if he required it, but he did not use this opportunity at all. The second overseas student was a Chinese speaking female from Malaysia, who had transferred to the University of South Australia at the beginning of the semester with two years credit, following completion of a Diploma in Civil Engineering with Honours from a Malaysian College. It was not felt to be either academically or culturally appropriate by the researcher to ask her to partner the Fijian student. At the completion of the first project, the Malaysian student approached the researcher to ask to be partnered with a local student in the second project, partly to assist her to get to know the students. The researcher approached some of the students in the class and they organised some partner changes to accommodate this.

## **The Curriculum Framework as Applied to the Case Study**

The framework used for evaluation of the curriculum in the case study has been detailed in Chapter 1. The following discussion examines how this framework has been used to examine the course *Building for People N*.

## **Intended curriculum**

### **Introduction**

The intended (or official) curriculum within university courses is not well defined as is more usually the case for K-12 courses of education, where state or national curriculum documents are commonly used. Most university courses have an approved curriculum framework, which consists of a course description that is approved by the faculty in the school and then some type of formal Academic Board of the University, when a new program is introduced. However, in subsequent years, and particularly for programs that have existed for many years, the curriculum of any course may be modified by individual faculty who teach it in successive years until it appears to be quite different from the originally approved formal documentation. This is not generally perceived to be a major problem, provided prerequisite knowledge for subsequent courses is still taught.

University programs that are designed for professional training such as medicine and engineering will almost certainly be required to meet accreditation requirements set by the relevant professional associations, so that graduates receive a degree that is recognised as suitable for professional practice in that country. These accreditation requirements will generally be assessed by the professional association on a four or five year basis during a visit to the University and the submission of various documents, including course curricula, by the University for examination. Hence course curricula in engineering are partially determined by accrediting bodies such as ABET in the USA and the Institution of Engineers, Australia in Australia. A more detailed discussion of accreditation requirements was included in Chapter 2 of this present study.

### **Generic and technical skills**

The intended curriculum for the course in this case study was developed to answer the first research question in the study, i.e. What do students of structural engineering need to learn in order to be able to design/construct engineering structures when they enter professional practice? The literature review detailed in Chapter 2 helped to develop the intended curriculum for the course by describing the needs of the engineering industry and the outcomes of several reviews of engineering education that have been conducted in various countries in recent years. The researcher also developed a concept map of structural engineering, based on her own industrial experience of 15 years, as an additional aid to developing the intended curriculum. This concept map is included as Appendix B4.

The intended curriculum that was finally adopted for the study was partially based on the guidelines for skills and knowledge of structural engineering developed by the Institution of Engineers, Australia, College of Structural Engineers (2000), which were also very similar to those of the Institution of Structural Engineers (2000) in the United Kingdom. Although these guidelines are intended for applicants for professional registration who have a minimum of three years practical experience in structural engineering since graduation, the guidelines can be used as an indication of the expected knowledge of a graduate engineer. The intended learning outcomes for the course incorporated both the technical skills from these guidelines and generic skills based on the accreditation requirements of both the Institution of Engineers, Australia (1999) and the Accreditation Board of Engineering and Technology in the USA (1999). The complete list of generic skills adopted for the study is given in Table 4.2 and the list of technical skills adopted is given in Table 4.3.

**Table 4.2 – Generic skills adopted for the intended curriculum of the course in this case study, Building for People N**

<b>Generic skills</b>
16. Ability to apply knowledge of basic science and engineering fundamentals.
17. Ability to communicate effectively, not only with engineers but also with the community at large.
18. In-depth technical competence in structural engineering.
19. Ability to undertake problem identification, formulation and solution.
20. Ability to utilise a systems approach to design and operational performance.
21. Ability to function effectively as an individual and in multi-disciplinary and multi-cultural teams, with the capacity to be a leader or manager as well as an effective team member.
22. Understanding of the social, cultural, global and environmental responsibilities of the professional engineer, and the need for sustainable development.
23. Understanding the principles of sustainable design and development.
24. Understanding of professional and ethical responsibilities and commitment to them.
25. Expectation of the need to undertake lifelong learning and capacity to do so.

**Table 4.3 – Technical skills adopted for the intended curriculum of the course in this case study, Building for People N**

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<b>Technical skills</b>
26. Understanding of the importance of all three basic principles of structure – stability, strength, serviceability.
27. Understanding loads (gravity, wind etc.) and how their effects are modelled in structural analysis.
28. Understanding the need to produce engineering solutions that are functional and economical as well as technically correct.
29. Having good knowledge of the properties of each of the materials normally used – steel, concrete.
30. Understanding the need for alternative load paths and the need to avoid progressive collapse mechanisms.
31. Having the ability to “visualise” failure mechanisms.
32. Having a good knowledge of modern techniques of structural analysis, design and construction.
33. Having a broad knowledge of relevant Australian standards.
34. Having knowledge of available analysis and design aids including computer programs and design manuals.
35. Having short-cut methods to check computer program outputs.
36. Having the ability to communicate design solutions through sketches and engineering drawings.

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### Curriculum plan

After the list of skills had been decided upon, a detailed intended curriculum plan was developed that tabulated for each generic or technical skill the intention, the implementation and the assessment. Questions used by the researcher to develop this plan were – “What am I trying to achieve?” (the intention); “How do I propose to do this?” (the implementation) and “How will I tell if this has been achieved?” (the assessment). For each skill, the implementation may have been through any or all of the projects, lectures, tutorials, practicals or site visits. In determining assessment, some skills were specifically mapped to marks allocated in the projects, using a detailed marking scheme that was issued to the students. Similarly, some skills were mapped to specific marks in exam questions. Other skills were assessed by overall achievement in the course, and others were not specifically assessed in this course, but assisted in developing a knowledge base that will be assessed in later courses. The complete curriculum plan is included as Appendix B5, with an extract from the plan included as Figure 4.2.



	<b>Intention – what am I trying to achieve?</b>	<b>Implementation – how do I propose to do this?</b>	<b>Assessment – how will I tell if this has been achieved?</b>
<b>Generic skills</b>			
Apply basic fundamentals	This is generic throughout the course. Students have previously studied mathematics, physics, chemistry, engineering materials, structural mechanics. This course is the first opportunity to apply that fundamental knowledge to structural design.	Throughout the course – lectures, tutorials, practicals, projects.	Through all components of assessment – exam, projects and prac reports. Difficult to separate proportions of skill learnt through each component. Overall assessment is probably the only valid measure.
In-depth technical competence	Also generic throughout the course.	Throughout the course – lectures, tutorials, practicals, projects.	Through all components of assessment – exam, projects and prac reports. Difficult to separate proportions of skill learnt through each component. Overall assessment is probably the only valid measure.
<b>Technical skills</b>			
Loads	An understanding of how to determine the design loads on a structure. An understanding of Limit State Design.	Lecture presented on Limit State Design and Wind loads. Project – requirement for calculation of loads in both projects.	Projects – marks allocated specifically for load determination. (not assessed in exam).
Functional and economic	An understanding that other factors influence design than just the numbers, particularly construction issues. This is developed further in later courses.	This will be discussed informally in lectures and project sessions. Site visit used to illustrate these issues.	Not specifically assessed.

**Figure 4.2 – Extract from the Curriculum Plan for Building for People N (see Appendix B5 for the complete plan)**

The complete curriculum plan in Appendix B5 showed that the researcher considered that only the first four generic skills were specifically addressed in the course in this case study. The remainder of the generic skills, numbers five to 10, were considered to be part of the overall structure of the civil engineering program and were not considered to be specifically identified as part of the curriculum plan. Similarly technical skills 14, 15 and 20 were not considered to be specifically addressed in the course in this case study. Material properties of steel and concrete were included in the curricula of pre-requisite courses, and alternative load paths and computer methods were part of the curricula of the subsequent course in structural engineering that the student cohort undertook in the following semester.

### Lesson plan

Following the development of the curriculum plan, the researcher then developed a specific Lesson Plan that is included as Appendix B6. The aim of the detailed lesson plan was to ensure that the projects were integrated successfully with the relevant lectures, i.e. that the students had seen the required theoretical background in lectures before (but not too long before) they needed to apply that theory in the design project. The lesson plan also was used to verify the timetable for the course that was included in the student course handout, as well as the 'Estimated completion date' column included in the student handout for each of the design projects. As with almost all courses in the civil engineering program at the University of South Australia, more than one faculty member was involved in teaching the course in this case study, *Building for People N*. The initials *MPR* that appear in the lesson plan are those of the other faculty member who gave the steel lectures and conducted the concrete practicals in the course. All other components of the course, i.e. the concrete lectures and both design projects, were conducted by the researcher. The lecture notes used for the steel lectures were jointly developed by the researcher and *MPR*, and had been used for the previous two years, so the content, delivery and timing of the lectures in the steel section could be relied upon by the researcher. An extract from the Lesson Plan is included as Figure 4.3.

<b>Week</b>	<b>Project Session</b>	<b>Lecture/Tutorial</b>
2 (Mar 5, 6)	Project – continue with wind load calcs as a “tutorial” External pressures Internal pressures Roof and wall bracing introduction Project schedule – By 12 March, complete wind load calcs., determine bracing layout	MPR Compression members
3 (Mar 12, 13)	Continue with roof/wall bracing Rafters, loads and restraint conditions Discuss setting out / presentation of calculations. Project schedule – By 19 March, complete bracing design	MPR Bending members

**Figure 4.3 – Extract from the Lesson Plan for Building for People N**

#### Learning objectives

The curriculum and lesson plans were documents developed by the researcher to articulate clearly what was intended for inclusion in the course curriculum and how this would be achieved. However, so that the intended curriculum should be clearly articulated to the students in the course, specific learning objectives were developed based on the researcher’s curriculum plan. These learning objectives were then documented in the course handout (Appendix B1) and were also specifically discussed in the introductory lecture of the course (the learning objectives were included on overhead transparencies used by the researcher in the lecture). The importance of being explicit in learning objectives was summarised by Felder et al. (2000) as follows “The more explicit you are about what you want the students to be able to do, the more likely they will be to succeed at doing it.” (p. 28) The learning objectives that were provided to the students for the course in this case study are presented in Table 4.4 (refer Appendix B1). The learning objectives provided to the students were more specific in some areas than the list of skills used in the curriculum plan. For example, ‘Broad knowledge of relevant Australian standards’ in the technical skills list has been made more specific by listing the particular Australian Standards that the students needed to use in the course for this case study.

**Table 4.4 – Learning objectives for the course Building for People N**

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<b>Learning objective</b>
37. To introduce the basic structural principles of stability, strength and serviceability and their importance in design.
38. To introduce the concepts of limit state design.
39. To enable students to understand and determine the design loads on simple structures arising from the design actions of gravity, occupation and use of the structure, and wind.
40. To apply the fundamental knowledge of materials and mechanics gained in earlier courses to the practice of structural design.
41. To gain technical competence in the following specific areas of structural analysis and design: <ul style="list-style-type: none"><li>• Analysis of simple structures to determine the axial loads, shear forces and bending moments and deflections on structural elements resulting from the application of the design loads.</li><li>• Design of the following individual structural elements in steel and reinforced concrete for strength, stability and serviceability:<ul style="list-style-type: none"><li>• Tension members</li><li>• Compression members</li><li>• Beams</li><li>• Members in combined bending and tension/compression</li><li>• Reinforced concrete slabs and footings.</li></ul></li><li>• Consideration of the stability of a complete structure under wind loads.</li></ul>
42. To become familiar with Australian Standards AS 1170.1, 1170.2, 3600 and 4100.
43. To develop the ability to communicate design processes and outcomes in a manner acceptable to the engineering profession, through calculations and drawings.

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## Summary

In summary, the intended curriculum was developed in response to the first research question of the study – *What do students of structural engineering need to learn in order to be able to design/construct engineering structures when they enter professional practice?* A literature review, the researcher's own industrial experience and the accreditation and registration guidelines of relevant professional bodies were used to formulate the answer to this question. The data sources that provide evidence of the intended curriculum as developed by the researcher and articulated to the students are the Course Handout, Design Project Handouts, Concept Map, Curriculum Plan and the Lesson Plan. These documents have been included as Appendices B1 to B6

## **Implemented curriculum**

Having developed the intention of what was to be learned in the course and detailed this in the documentation discussed in the previous section, the next question to be answered was the second research question of the study, i.e. How can these learning requirements be implemented through a project-based curriculum?

### **Curriculum and project types**

The first point requiring discussion is the nature of the curriculum within the course in this case study and the civil engineering program at the University of South Australia with regard to the definitions of project-based learning detailed in Chapter 3. According to Heitmann 's (1996) definitions, the civil engineering degree program at the University of South Australia could not be defined as a project-organised curriculum, since projects are not used as the structuring principle of the entire curriculum of the program. However the program and the course in this case study, *Building for People N*, would clearly fit Heitmann's definition of project-oriented studies. In accordance with this definition, the traditional technique of information provision through lectures and tutorials was still part of the course in this case study, representing approximately 70% of the formal contact hours in the course. However, the primary objective of the researcher was to ensure that all of this information was subsequently required to be applied by the students in the completion of their design projects.

The design projects used in the course in this case study most closely fit the profile of Assignment projects as defined by Kolmos (1996) and discussed in Chapter 3 of this present study. The problem was reasonably well defined at the start, being based on architectural drawings where dimensions, structural materials and the basic structural system had already been selected. In addition, the researcher required the students to design only specific aspects or components of the structures, partly to ensure that all students would gain experience in design of the fundamental structural members in each material (beams, columns, tension members, etc.) but also to ensure that the scope of the project was reasonable in terms of workload. However, students were not constrained to a correct solution of the project and decisions on such things as wind speed categories, member types and sizes were left to the students. Consequently, no two project solutions submitted were identical, and no correct solution was either determined by the researcher or distributed to the students (although detailed feedback was provided to each student on the appropriateness of their chosen solution).

The Curriculum Plan (Appendix B5) detailed the proposed implementation of those generic and technical skills of the intended curriculum that the researcher felt were relevant in the course. Of the four generic and eight technical skills that were intended to be implemented in the course, all but one (visualise failure mechanisms) was intended to be partially or wholly implemented within the project component of the course. Whilst information relevant to most of these skills was intended to be presented within lectures and tutorials, the intention in the projects was that the skill would be developed and applied by the student, not just listened to. The student's development of the skill was then assessed through the allocation of marks within the project specific to that skill as discussed in the achieved curriculum section.

### Classroom observation, videotaping

Whilst the curriculum and lesson plans state the researcher's planned implementation of the curriculum, it was necessary for the validity of this study to ascertain whether the intentions were actually implemented in practice during the teaching of the course. The data that were collected to determine the implemented curriculum within the case study included observations from the researcher's journal and observation records from videos that were made of each project session. Unfortunately the researcher was not able to secure the participation of an independent observer to attend any of the project sessions, so the videotapes were used as the next best option. The video camera was positioned on a tripod and kept in a stationary location for the whole session. The camera was positioned to enable as much of the classroom as possible to be viewed, but it was not possible to have the entire class within range in each session. The camera was switched on by the researcher at the start of each session (or as soon as she remembered it) and was left running without interference for the length of the tape. The videotapes were 65 minutes long. Project sessions were scheduled to be of 110 minutes duration, but often finished earlier if everyone's questions had been answered. Activities that occurred after the tape ran out were recorded in the researcher's journal. The tapes are available from the researcher for perusal as required.

The lecture/tutorial sessions were not videotaped because the project-based component of the course was being evaluated and the study did not attempt anything different in the lecture sessions than would be expected from this traditional teaching method. However, it should be noted that with the relatively small class size and the researcher's normal lecturing style, the lecture sessions were probably more informal than is typical within university settings. In addition, due to the timetabling of three-hour blocks for the lecture and tutorials in the course, they were presented in an integrated manner, such that it was usual for the formal

lecture not to continue for more than 40 minutes or so before breaking for students to undertake a tutorial.

### Researcher's journal

The researcher's journal was kept throughout the duration of the case study. The journal was used to record the progress of each session, what happened in the sessions, the researcher's thoughts about aspects that could have been improved in sessions, to note items that she needed to bring up in a future session, a record of which students were absent, and other such details. In addition, the journal was used to record the researcher's thoughts on how various students were progressing in the course at various stages, as well as keep a record of all student approaches with questions or concerns outside of class hours.

### Student journals

Students were asked to keep personal journals throughout each project. Limited guidance was given to the students on the format of such journals, however they had been required to keep journals in one of their first year courses, and a brief discussion was held during the introductory lecture in the course in this case study as to the information that they should contain. Some students used the journal as a kind of timesheet, with only dates, times and brief details of the tasks they had undertaken during that time entered into the journal. Others used them as a more reflective tool, detailing their progress, noting questions they were unsure of and their feelings of frustration or achievement. Journals were required to be submitted with their project and a small percentage of marks was allocated to them, as a minor incentive for them to be kept. In the first project, nine students did not submit journals, but in the second project, all but three students submitted journals.

Student journals give evidence of the implemented curriculum where they have recorded factual information about what was discussed in a class session. They also provide evidence of whether the curriculum was implemented according to the instructional principles of constructivism (refer Chapter 1) and those of project-based learning (refer Chapter 3). Since the reflections of students in their journals are records of their perceptions of what happened as well as factual information, student journals have been considered as data sources for both the implemented and the perceived curriculum.

## **Perceived curriculum**

### **Introduction**

Despite the most careful plans of the curriculum developer as to what students are intended to learn, and however carefully and exactly these intentions are implemented, it may still be possible that the learning outcomes that the students perceive from a course may be quite different from those the teacher intended and implemented. Hence the analysis of student perceptions of a curriculum is a critical part of the evaluation of its effectiveness. This analysis will assist in answering the third research question of the present study, i.e. What do engineering students perceive as the relevance of project-based learning to the professional practice of structural engineering?

### **Data sources**

To evaluate students' perceptions of the relevance of project-based learning to their future professional practice, the researcher's original intention was to adapt a suitable evaluation instrument from previous work in related areas that had been statistically validated in previous studies. Such an instrument would have involved a series of questions with a Likert scale response system, and could have been based on those developed for science learning environments (e.g. Fraser, 1998). However, after examination of many of these instruments it was decided that none were appropriate for this study, as they were generally developed for high school or primary school age students and were not appropriate to university learning environments. Additionally the aspects of curriculum that they evaluated were not specific enough for the purposes of this case study. Many previous studies in engineering that had involved course evaluation instruments were also examined, however, all of the studies had been too small to undergo a statistical validation process. Since the sample size in this study was also small it was decided to abandon the approach of using a single, generalist, validated evaluation instrument in favour of one that was specifically developed for this study, combined with other data sources. These multiple data sources were student journals, email correspondence from students and the course homepage discussion list, concept maps, student interviews, a Course Evaluation Questionnaire, and a Perceived Curriculum Evaluation instrument.

### **Student journals**

As discussed earlier, student journals provide evidence of both the implemented and perceived curriculum.



### **Student emails and discussion lists**

Each course that is taught within the University of South Australia is allocated a homepage, that staff can use to provide electronic access to lecture notes or presentations and any other relevant documents. All students who are enrolled in the course are able to access the homepage. Additional features are available on the homepages, including an electronic discussion list facility. For each project, the researcher set up a discussion list and posted an initial message suggesting that the students could use this facility both to get quick answers to questions they had of the lecturer and to discuss problems between themselves. However, no students accessed the discussion list for the duration of the project.

In lieu of the discussion list, students continued to access the researcher via email with questions when they were outside of class time, or when they could not find the researcher in person. These email records were retained by the researcher as another data source for the implemented and perceived curriculum. However, the majority of communication between the researcher and the students took place through consultation in the project sessions or through students visiting the researcher in her office to ask questions between sessions. These interactions were recorded in the researcher's journal.

### **Concept maps**

As mentioned in the previous discussion on the intended curriculum, the researcher developed her own concept map of structural engineering to assist with the curriculum development. It was decided that students' concept maps of structural engineering would be a useful indication of their initial understanding of the field if they were included in their journals at the commencement of the course. If students were then asked to draw a second concept map of structural engineering at the conclusion of the course, the maps could be compared to evaluate how their perceptions and understanding of structural engineering had changed during the course in this case study.

The shortcomings with this idea were twofold. Firstly the students had little prior experience of concept maps (on questioning during the first lecture, some had done them in high school, but most had not), and there was insufficient time to develop their understanding of them in the course, as it was not a high priority. Secondly, and partly as a result of learning that students did not have experience with concept maps, the production of the maps in their journals was made optional by the researcher. Consequently, only one student produced a map and that was at the start of the course. However, this map did provide an additional useful data source of one student's perceptions and is discussed in Chapter 6.

### **Student interviews**

One of the most direct data sources available for determining students' perceptions is to talk to the students directly, through interviews. At the commencement of the course in this case study, during the introductory lecture, the students were informed that the course was being used as a case study for the researcher's doctoral studies and that the project sessions would be videotaped. Each student was then given an information sheet that also called for volunteers to be interviewed about the course at its conclusion. A consent sheet was attached to the information sheet. This document has been included as Appendix B7.

The response from students was positive, with seven students initially volunteering to be interviewed. Interviews were subsequently conducted during the break between semesters, after the completion of the final examination for the course. For reasons of availability of the students and researcher, eventually only four students were interviewed; two of these students who had worked as a pair on both projects chose to be interviewed together and the remaining two students were interviewed individually. A Focus sheet was developed as the basis for the interviews and this has been included as Appendix E1. The focus sheet was framed around the research questions of the study, examining what students felt were the critical concepts of the course, which of the teaching and learning methods in the course they found most useful, their perceptions of the projects as learning tools and their opinions on the value of project-based learning within structural engineering. Interviews were recorded on audiotape and then transcribed by an administrative assistant with prior experience in this work. The interview transcripts were then edited by the researcher, only to the extent of adding or changing words that the transcriptionist could not understand on the tape, such as technical terms related to structural engineering. Outcomes of the student interviews are discussed in Chapter 7.

### **Course Evaluation Questionnaire**

The Course Evaluation Questionnaire administered to the students was a standard 5-point Likert scale questionnaire required to be completed for all courses taught at the University of South Australia. The first 10 statements were generic to all courses and were specified as required questions by the university. These statements relate to teaching standards, assessment and feedback, workload and clarity of information provided. The other 10 statements were selected by the researcher from an allowed set of standard statements issued by the university, and focussed more on the information of interest to the study. Two open-ended optional response questions also were included. A copy of the Course Evaluation Questionnaire used in the study has been included as Appendix B8. The Course Evaluation Questionnaire was administered to the class during the penultimate week of semester.

Provision is made on the course homepage for the evaluation instrument to be completed on-line, however, experience in previous courses by the researcher and other faculty has shown that students do not complete the evaluation if it is left as a task for them to do on-line in their own time. Consequently, the Course Evaluation Questionnaire was administered to the class as a paper handout, 10 to 15 minutes of class time was allowed for completion prior to being collected by the researcher and collated.

#### **Perceived Curriculum Evaluation instrument**

The Perceived Curriculum Evaluation instrument was a questionnaire specifically developed by the researcher for this study in order to answer the third research question. The instrument is included as Appendix B9. The lists of generic and technical skills in Tables 4.2 and 4.3 that were used to frame the intended curriculum were also used to develop the Perceived Curriculum Evaluation questionnaire. Two aspects of student perceptions were examined. The first was the students' perceptions of which of the generic and technical skills listed they perceived would be important to them if they were employed as a graduate structural engineer. Responses to this question were based on a 5-point Likert scale response ranging from 1 as Very unimportant to 5 as Very important. A sixth option of Not applicable was also available. The second aspect examined was the students' perceptions of where they believed that they learned each of the skills within the course in this case study. For this part of the instrument students were able to tick up to three choices per skill, from lectures/tutorials/practicals, design project or self-study. Alternatively they could tick the option of no opportunity in this course. An extract from this section of the evaluation instrument is included in Figure 4.4.

A pilot study was undertaken with students taking the course *Building for People N* in the year 2000, preceding the case study, to trial the evaluation instruments for the perceived curriculum. Following the pilot study, the instrument was altered to a 5-point Likert scale rather than the original 3-point scale, but other than that the format and content was considered to be successful and was then used in the case study. The Perceived Curriculum Evaluation was administered in hardcopy format, similar to the Course Evaluation Questionnaire, and was given to students in the final week of semester, with some class time allocated to enable its completion and collection.

C. Where do you believe that you gain skill or knowledge in these areas in the course Building for People N (noting that not all of the areas may be covered in this course)? Please tick boxes in each line (you may have from 1 to 3 ticks in any line).

	Lectures/ Tutorials/ Practicals (formal contact hours)	Design Project (formal contact and outside hours work)	Self-study (any other work outside formal contact hours)	No opportunity in this course
Ability to apply knowledge of basic science and engineering fundamentals.				
Ability to communicate effectively, not only with engineers but also with the community at large.				

**Figure 4.4 – Extract from the Perceived Curriculum Evaluation instrument**

### **Achieved curriculum**

The final stage in the curriculum evaluation process undertaken for the case study was that of the achieved curriculum. This evaluation stage was used to answer the fourth research question of the study, i.e. How effectively do engineering students achieve the intended learning outcomes using a project-based approach?

This is probably the most difficult stage of the evaluation. As discussed in Chapter 3, the major difficulty in assessing the effectiveness of project-based learning is deciding what criteria to use. Some would argue that students should be able to pass a standard examination in a topic area, regardless of the means by which the course was taught. However, as discussed by Heitmann (1996) and illustrated by the example from Lenschow (1998) in Chapter 3, this means of evaluation is not valid, as the skills developed by project-based learning are more than just technical knowledge that can be assessed through standard tests or examinations. Instead of a single examination, it is recommended that a variety of evaluation methods need to be employed to evaluate the outcomes of project-based learning.

The course in this case study included both projects and a traditional examination as components of the course assessment. Since the intended, implemented and perceived curriculum evaluation stages were all framed around the set of generic and technical skills listed in Table 4.2 and Table 4.3, these same skills formed the basis of the achieved curriculum evaluation. This aspect was accomplished in the projects by clearly articulating the marking scheme to the students, and then mapping that marking scheme to the list of

skills for the intended curriculum. The marking scheme was given to the students as part of the project handout for each of the projects (refer Appendices B2 and B3). However, the mapping of those marks to specific skills from the intended curriculum list was not communicated to the students, as it was not really relevant to them. The mapped marking schemes were developed as separate documents by the researcher, using the same format as the marking scheme given to the students, but with the third column replaced by Skill type and no. The marking schemes for the projects are included as Appendices B10 and B11, with an extract given in Figure 4.5. In the third column, “T” referred to a technical skill with “G” used for a generic skill (although not represented in the selection shown in Figure 4.5). The number referred to the number of the skill as listed in Table 4.2 or Table 4.3 and the (b) was used to differentiate between the assessment of the skill in the examination, designated (a), and the projects, designated (b). For example T12 (b) under Slab panel A indicated that 4% of the marks in that component of the project assessed achievement of the skill “Understanding loads (gravity, wind etc.) and how their effects are modelled in structural analysis” in the design project. Technical skill 17 had two skill components that were examined or within the design project, hence 17(a) and (c) were within the examination mapping and 17(b) and (d) were within the design project mapping. Marks for each skill were then totalled for both projects and used as a measure of how well the skill had been achieved or not. Full details of the evaluation are discussed in Chapter 6.

Item	Allocated %	Skill type & no.
Slab Panel A (one-way):	11	
Determine thickness for serviceability using Warner’s method	2	T11(b) & T17(d)
Determine design loads, bending moments & shears in accordance with Sec 7.2	4	T12(b)
Design reinforcement for bending, check minimum.	3	T11(b) & T17(d)
Design reinforcement for crack control etc.	2	T11(b) & T17(d)
Slab Panel B (two-way):	9	
Using same thickness as Panel A, determine design loads, bending moments to Sec 7.3	3	T12(b)
Design reinforcement for bending, both directions	4	T11(b) & T17(d)
Check reinforcement for crack control etc.	2	T11(b) & T17(d)

**Figure 4.5 – Extract from mapped marking scheme for Project 2**

The same scheme also was used to map the marks given in the examination to the generic and technical skills. A copy of the examination paper and the mapped marking scheme developed for it are included as Appendices B12 and B13, respectively.

In addition to the specific mapping of marks to skills discussed so far, it was also noted in the curriculum plan developed by the researcher (Appendix B5), that in some cases it was difficult to separate the proportions of skill learnt through each component of the course (i.e., to differentiate between the projects and examinations). In these cases, overall assessment was considered to be the only valid measure of achievement, particularly for the generic skills. Further, some of the skills were not considered to be specifically assessed in the course at all. This did not mean that the skills were not discussed or developed within the program, just that there was no assessment that could be considered to be specifically related to them within the course in this case study.

### Summary of data sources

In the preceding discussion, various data sources used within the case study were described and related to each of the four stages of curriculum evaluation in the study. In keeping with the principal of triangulation or multiple method research, the results from these multiple data sources are compared and related in the subsequent chapters. The primary data sources utilised, the curriculum evaluation stage for which they were relevant, and the Appendix in which the document is contained, if applicable, are summarised in Table 4.5.

**Table 4.5 – Sources of data collected in the case study**

<b>Data source</b>	<b>Curriculum stage</b>	<b>Notes</b>
Course and project handouts	Intended	Refer Appendices B1 to B3
Curriculum plan	Intended	Refer Appendix B5
Lesson plan	Intended	Refer Appendix B6
Researcher's journal	Implemented	The researcher's journal of observations and reflections was kept for the duration of the course
Videotaped project sessions	Implemented	All but two project sessions were videotaped
Student journals	Implemented & perceived	Reflective journals were kept by students during both design projects
Email correspondence from students	Implemented & perceived	Students were free to email the lecturer at any time during the course with questions or problems
Webpage discussion lists	Implemented & perceived	As mentioned, these were available for students but were not utilised by them

Concept maps	Perceived	Developed by the researcher and the class. Refer Appendix B4
Course Evaluation Questionnaire	Perceived	This was a standard evaluation instrument used by the university, with some questions specifically selected for the study. Refer Appendix B8
Perceived Curriculum Evaluation	Perceived	This questionnaire was developed specifically for the case study. Refer Appendix B9
Student interviews	Perceived & Achieved	Four student volunteers were interviewed at the conclusion of the course. Refer Appendix B7
Design project assessment results	Achieved	Marking schemes were developed for the projects that mapped specific marks to specific generic and technical skills. Refer Appendices B10 & B11
Examination results	Achieved	A similar mapped marking scheme was developed for the examination. Refer Appendix B13

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## Validity and Reliability

### Introduction

One of the crucial questions to be answered by the researcher when conducting qualitative research such as this case study is “How can the reader trust the qualitative findings of the study?” In other words, the researcher must demonstrate that the data collected are valid and reliable, as are the results and conclusions that are determined from them. This demonstration is even more critical in the case of this study because it relates to the field of engineering, where the standard research methodologies familiar to practitioners are quantitative methods framed within a positivist paradigm. Engineering researchers are expected to demonstrate the rigour of their quantitative research, although they may use different terminology from qualitative researchers. They need to provide a description of the set-up of their experiments, their testing and data collection techniques, the methods of data analysis they have used and then use these descriptions along with a review of previous work in the area to prove the validity of their conclusions. Demonstrating the validity of qualitative research follows a similar path, but the measures and indicators used may be different, as discussed below.

Many terms have been used by qualitative researchers to describe these issues, but the ones that have been adopted for this study are those of Merriam (1998) – internal validity,

reliability, external validity and ethics (or objectivity). Guba and Lincoln (1989) state that these terms are derived from the positivist paradigm and that the parallel criteria within the constructivist paradigm are credibility, dependability, transferability and confirmability. However, while the distinction between these terms is one that the educational philosophers may debate at length, for the purposes of this study they have been used interchangeably, with the positivist terminology being adopted because it is more likely to be familiar to engineering readers of the study.

### **Internal validity**

Internal validity or credibility refers to how research findings match reality. However, the difficulty with this definition is the meaning of reality. According to Merriam (1998), "One of the assumptions underlying qualitative research is that reality is holistic, multidimensional, and ever-changing; it is not a single, fixed, objective phenomenon waiting to be discovered, observed and measured as in quantitative research." (p. 202) Hence what is being observed in qualitative research are "people's constructions of reality – how they observe the world." (p. 203) And since people are the primary instrument of data collection in qualitative research, their interpretations of reality are accessed directly by the researcher through observations and interviews. Thus, internal validity is actually a strength of qualitative research since the researcher is closer to reality through personal contact than if a data collection tool or instrument was used that prevented a direct link between the researcher and the people being observed.

Merriam (1998) suggests six basic strategies that can be used to enhance internal validity or credibility within a qualitative research study: triangulation, member checks, long-term observation, peer examination, participatory or collaborative modes of research and researcher's biases. In the current study three of these strategies have been adopted. Triangulation has been used since multiple sources of data and methods of data collection have been utilised and their meanings compared within the case study. Long-term observation was undertaken since the study extended over the full duration of the semester course, all project sessions were observed or recorded and all students were observed over the length of the course, not just occasional sessions or individual students. The opportunity for peer examination and participatory research was limited in this case to the involvement of the researcher's doctoral supervisor, since the study was required to be the researcher's original work under the rules governing doctoral research presentations. The researcher's biases and background were discussed quite extensively in Chapter 1 of the study so that her assumptions, views and theoretical orientation were made clear to the reader from the outset of this thesis.



## Reliability

The traditional understanding of reliability or dependability in a research project is that if a subsequent researcher undertook the same series of tests or experiments, following the methodology of the original research, then they would achieve the same results as the original researcher. This understanding is clearly impossible to apply to qualitative research and particularly case studies because the participants in the study are human and human behaviour will never be replicated. For example, if a different researcher repeated the present study using exactly the same projects, lectures and curriculum framework, and repeated the study with the subsequent cohort of students undertaking *Building for People N* in 2002, the outcomes could not possibly be exactly replicated. Clearly one of the major differences would be that a different student cohort would be involved, hence their results and opinions would be different. In addition, the teaching and learning experience, and industry background knowledge of the researcher would also be different, so the interpretation of outcomes may also differ.

Since the traditional interpretation of the term reliability is not applicable for qualitative research, Lincoln and Guba (1985, p. 288) have suggested that the dependability or consistency of the results obtained from the data should be used as the qualitative research equivalent. This means that while it would not be possible for a second researcher to obtain the same results if repeating the study, it should be possible that a second researcher would concur that, given the data collected, the results make sense. Merriam (1998) suggests several techniques that can be used to ensure that results are dependable – stating the investigator’s position, triangulation and an audit trail.

In the present study, the investigator’s position regarding the assumptions and theory behind the study were discussed in Chapters 1 to 3 and a description of the student cohort being studied and the social context from which the data were collected has been included in this chapter. Triangulation through the use of multiple methods of data collection has already been discussed under internal validity, but is also relevant to reliability. An audit trail refers to an explanation of how the study results were arrived at through a detailed description of how data were collected and how decisions were made through the study. This chapter has detailed extensively the methodology used for data collection in the study and subsequent chapters will describe the further decisions made regarding data analysis and interpretation. Thus the reliability or dependability of the study has been addressed through all of these techniques.

## **External validity**

External validity or transferability refers to the applicability of the findings of one study to another situation, or in other words, how generalisable the results are. Again, there are difficulties in applying this concept to qualitative studies and various interpretations of it have been proposed including working hypotheses, concrete universals, naturalistic generalisation and user generalisation (Merriam, 1998). Of these interpretations, that of reader or user generalisability most closely satisfies one aim of this study. This leaves the extent to which a study's findings apply to another situation up to the people in those situations. In other words the readers of the study decide what aspects can be applied to their own situation, and what aspects do not apply. For example, another researcher may use the curriculum evaluation technique for projects detailed in this study to evaluate projects in another area of engineering or another field altogether, even though the details of the intended curriculum (such as the list of generic and technical skills) may not apply to that field.

To enhance the possibility of transferability of a qualitative study's findings, Merriam suggests three strategies that can be used: rich, thick description; typicality or modal category; and multisite designs. (Merriam, 1998, p. 211) Rich, thick description requires enough description of the current study to enable readers to determine how closely their situations match that of the research study, and hence how transferable the findings may be. This strategy has been adopted in the current study through the extensive detail provided in this chapter and the appendices. Typicality has also been partially addressed by providing a detailed description of the students, course and program in the study, thus enabling comparison with other programs described in the literature review and enabling readers to make comparisons with their own situations. Multisite design was not part of this study.

## **Ethics**

The research program discussed in this thesis received ethics approval from the Curtin University Human Research Ethics Committee. Since the topic was not particularly personal or controversial, the only ethical issues that required major consideration were the confidentiality of any data collected, and the dual roles of the author as both researcher and teacher. The identity of all students has been protected by using only their initials in any data analysis or quotations from them. All data collected for the study will be kept in secure storage for the minimum required duration of seven years.

The dual roles of the author as researcher and teacher did not present any obvious problems during the study. This was partly due to the fact that the participants were adults and hence

capable of making mature decisions about their participation. It was stressed to the students at the start of the course in this case study that the research would be incidental to their participation in the course, i.e. that the course would still be taught in exactly the same way as it would have been otherwise (although probably more carefully thought out and planned than usual). In addition, the students' grades would not be affected in any way by the research study. Information on the study was provided to the students at the start of the course. Participation in interviews was voluntary. Class time was not used by the researcher to record or gather data at the expense of teaching the course, notes in the researcher's journal were made outside of class time. The only real sign to the students of anything different was the videotaping of the project sessions, which was agreed to by all of the students. However, as described earlier in the chapter, the camera was positioned at a stationary location for the class duration and was just switched on by the researcher and then allowed to run until the tape ran out. This did have the disadvantage that the picture was occasionally obscured if a student stood in front of it to talk to another student or the researcher, but this only happened infrequently. Students made reference to the camera only in one recorded session, when a joke was made about getting a close-up of a particular student.

## **Summary**

This chapter has described in detail the background to the case study including the nature of the engineering program at the University of South Australia, the course itself, the projects within the course and the student cohort who undertook the course in the semester it was researched. The curriculum framework used for evaluation within the study was clearly articulated and described including excerpts from critical documents that have been included in full as appendices. Finally, the validity and reliability of the research has been examined and discussed. In subsequent chapters, analysis of the outcomes of the various data collected is made.

# Chapter 5 – The Intended and Implemented Curricula

## Introduction

This chapter briefly reiterates the development of the intended curriculum for the course in the case study. The implementation of the intended curriculum and an evaluation of whether these intentions were implemented in practice in the course are discussed in the subsequent section of this chapter.

## The Intended Curriculum

The intended curriculum for the course in this case study was developed in response to the answer to the first research question of the study, i.e. What do students of structural engineering need to learn in order to be able to design/construct engineering structures when they enter professional practice? The development of the intended curriculum, discussed in detail in Chapter 4, was based on the outcomes of the literature review detailed in Chapter 2, in particular the accreditation and registration guidelines of professional engineering bodies, and the researcher's own industrial experience (summarised by the concept map included as Appendix B4). The answer to the research question was developed as a list of generic and technical skills (see Tables 4.2 and 4.3) that engineering graduates should have if they wished to enter professional practice in the field of structural engineering. This list was then used to develop a curriculum plan and lesson plan for the course in this case study (Appendices B5 and B6) which in turn were used to frame the learning objectives included on the course handout to students (Appendix B1). The evidence for the intended curriculum of the course lies within these appendices and the literature review of Chapters 2 and 3.

The lists of skills in Table 4.2 and Table 4.3 provided the detail of the content of the intended curriculum. The other component that must be considered, according to the definitions of curriculum cited in Chapter 1, is how this content is taught or implemented, i.e. the learning experiences that are provided for the students to be able to develop their understanding. For the course in this case study, these learning experiences involved a combination of traditional lecture/tutorial sessions and two major design projects. The intention of the project-based learning experience was to implement the instructional principles deriving from social constructivism as developed by Savery and Duffy (1998) and detailed in Chapter 1. In summary, the intention was to provide students with an authentic

learning task that reflected the complexity of the professional structural engineering environment, while also providing them with the opportunity to develop their understanding through social interaction with their peers and the lecturer, as well as personal reflection.

## **The Implemented Curriculum**

### **Introduction**

In Table 4.5, several data sources were noted that could be used to examine the implemented curriculum in the course in this case study – the researcher’s journal, videotape observations, student journals and email correspondence. A comparison of data from these sources with the intended curriculum contained within the curriculum and lesson plans can be used to determine the extent to which the intentions were implemented.

### **Lesson plans and scheduling**

As with any real life situation, the best-laid plans may not always turn out exactly as originally intended. For various reasons, this was true for the case study with regard to the original class schedule issued to the students in the course handout (Appendix B1), and the original Lesson Plan developed (Appendix B6).

One issue that unfortunately arose during early March was that the researcher’s father-in-law was diagnosed with a terminal illness and died three weeks later. This obviously meant that the researcher was somewhat distracted during this period and afterwards, and some classes were also rescheduled during Weeks 4 and 6 to enable the researcher to take some leave for family time. Consequently the Lesson Plan actually implemented differed from that in Appendix B6 as follows:

- Week 4, the project session originally scheduled for Monday 19 March from 1 to 3 was rescheduled to 9 to 10 that day instead.
- Week 4, the researcher was unavailable for consultation by students after the Monday morning session, except for a short time on Thursday morning, due to personal leave.
- Week 6, the project session was rescheduled from Monday 1 to 3 to Tuesday 12 to 2, due to bereavement, then the researcher was unavailable for consultation on Thursday and Friday of that week.

These schedule changes did not affect the timing of lectures since they were being conducted by the second lecturer involved in teaching the course (MPR) at that stage of the course. The major impact was the loss of consultation time available with the researcher for the students, and the poor attendance at the rescheduled class on 19 March 2001 as noted in the researcher's journal for that day (the researcher's initials JM have been used to refer to her journal or where students have referred to her in their journals):

Class was disappointing today. Rescheduled to 9 to 10 due to my leave this week but found out that students had a test scheduled in the following class at 10.00, so several didn't come. Probably means I will need to repeat much of it...Advised class that I would be available on Thursday approximately 11.30 to 1 for questions in my room. (JM, 19 March)

As predicted, this then affected the scheduled class the following week on 26 March, 2001 when the researcher's journal notes "Then, as expected, had to go right back through rafters etc. again for a group that were not there last week (although a couple chose to sit in for review)." (JM, 19 March)

As a result of the unavailability of the researcher for student consultation at various times during the first project for these reasons, the submission date was extended two days to Thursday 12 April, with additional consultancy times scheduled during the three days prior to the submission date. However, overall the impact of these changes on the students was negligible and rated only passing comment in some student's journals, but none in course evaluations. In terms of the order of the lectures and project progress, that is, that the students were presented with the theoretical background in lectures before they were required to apply it in the projects, there was no change, except that the application was delayed by only a few days from the original lesson plan. The steel projects were still marked during the mid-semester break as per the lesson plan with the first half-hour of the project session on April 23 used to hand them back and provide feedback to the class.

During the second project, the reinforced concrete house, the original lesson plan intended that an additional lecture session would be scheduled during Week 7 to enable students to have sufficient theory to start on the project in the following week, when the researcher was away at a conference. However, due to earlier schedule changes, the class did not have a time on Friday when they could all meet for a make-up lecture. Consequently an additional hour of lectures was added to the Tuesday session in Week 7, and the amount of material covered in lectures during the first week was considerable. From the researcher's journal on 27 April, 2001:

I know that I hurried through more than usual but I was still reasonably satisfied with how it went. I have asked students to spend the next 2 weeks until I see them on 7 May in going through the tutorials themselves, doing the reading from text and going through RC Aus topics. Also to read the project handout, get their heads around the drawings and come with questions. They do have sufficient background to try Slab Panel A and I think some will start but not all. Anyway there is still time as far as the project schedule is concerned. (JM, 27 April)

[Note: RC Aus is a software package on reinforced concrete design to the Australian Standards that students could download for free, as well as access in the computer pools rooms. It contains a lot of pictures of reinforced concrete construction as well as text explanations, quizzes etc. It was recommended to students as an additional self-learning resource to supplement the textbook and lecture notes]. At the next project session on 7 May, these expectations were confirmed with over half the class having made a good attempt at Slab Panel A design and the others not having started. However, this initial schedule change again did not seem to cause any long term issues, and was not commented on by students in their journals. The only other schedule change during the second project was the swapping of a lecture from 5 June to 4 June with the project session swapped to the lecture slot. Attendance at both sessions was good, so this had no real effect on the curriculum.

The final issue related to scheduling that occurred was that the second lecturer involved in teaching the course (MPR) decided to carry out the practical component of the course using a single group rather than half the class each week over two weeks for each practical, as originally scheduled. He did not advise the researcher of this, or that he had moved the date of the concrete column practical from Week 11 to Week 9. This meant that the students undertook the column practical and were required to submit the write up before they had been given any of the column theory, which was scheduled and delivered in lectures in Week 11. Unfortunately, the researcher remained unaware of this issue until several students wrote about it on the Course Evaluation Questionnaire. This was disappointing from two respects – firstly, that the problem could have been avoided with better communication between MPR and the researcher, and secondly that it meant some students commented on that aspect rather than something else on their Course Evaluation Questionnaire.

As discussed above, there seemed to be no major effect from the various scheduling changes on the implementation of the curriculum with respect to lecture content and project outcomes, but the value of the column practical was certainly reduced considerably by its change in schedule. The only other issue that arose that did detract from the intended

curriculum was that the site visit that had been planned did not occur, as described in the researcher's journal on 30 May, 3001:

Also unfortunately our site visit will not happen. Due to the wet weather the program on the site we had proposed to visit is nearly 4 weeks behind so they are still driving piles rather than casting slabs. We will go in August. Connell's other projects are not at a suitable stage and it is too late to organize anything else, so that is disappointing. (JM, 30 May)

The site visit had been planned to enable the implementation of skill 13 regarding the functional and economic nature of engineering solutions, as well as to provide an overall practical view of the course content. This was disappointing for both the researcher and the students, and it is difficult to gauge what effect it may have had on the achieved curriculum outcomes for various students. Several students did already have site experience from vacation or other work experience, but for some students without that benefit, the site visit could have been very useful.

### **Video observations**

As detailed in Chapter 4, videotapes were made of eight of the total of nine project sessions during the semester. The final session on 5 June 2001 was not taped. The decision to videotape sessions was made only just before the start of the course when it proved impossible to organise an experienced independent observer to attend the sessions. However, the videotapes resulted in a wealth of information about the researcher's and students' activities in the project sessions. The videos were not analysed until the completion of the course, but were checked to ensure that they had worked satisfactorily. This was mostly due to insufficient time available to the researcher during the semester, as it could have been useful feedback to analyse them during the teaching semester. However, it did give the researcher time to reflect on what the videos actually meant in terms of data they provided. A focus sheet was developed by the researcher before undertaking the analysis of the tapes to examine this question and determine a suitable means of analysis. This focus sheet is included as Appendix C1. The fundamental questions that the videotapes could be used to answer were as follows: Are sessions different from formal lectures?; Is the researcher's role different to normal lecturing?; Do students use this time well – or maybe better phrased as “are students active learners in these sessions”?; and Is there a correlation between active participation in these sessions and good assessment results for certain students and vice versa?



The answers to these questions were developed by analysis of the tapes in the following manner. Each tape was first skimmed through to ensure there were no technical difficulties and to get a general impression for what happened in the session. This was cross-checked with the researcher's journal to note any discrepancies and to clarify activities that may have occurred in the session before the tape started or after it had run out. (In general the tape was switched on just before the session started, after some students had arrived, but this varied slightly, as for example when the class toured the adjacent industrial shed first.) The tape was then rewound and analysed in more detail. For each session, a seating plan was drawn as the students were seated at the start of the tape. Students who arrived later were added to the seating plan, and some students who were present at the start of the session but left early (presumably because they had no questions to ask) were recorded on the videotape, but had been marked absent by the researcher on the attendance sheet. Similarly some students who were not in view (due to the camera angle) at the start of the tape were added into the plan when their seating position became known, if they got up and came into view to talk to another student or similar activity. The attendance sheet was not required by the university, but was kept as an additional record for the researcher's use, however, it was usually not marked until later in the session after the researcher had circulated to answer questions. Hence the videotape provided a useful cross-check on this information.

After the seating plan was completed, the tape was wound back to the start and notes were made of activities as they occurred, using the tape counter (minutes and seconds from the start) in the left hand column with the activity noted in the right hand column. The analysis was recorded by hand and the raw data are available from the researcher for perusal. Data for two sessions chosen as typical examples, on 12 March (first project) and 7 May 2001 (second project), is included as Appendix C2. Activities that were recorded included the researcher's activity at all times (e.g., talking to the whole class, talking with a particular student or group of students) and any significant activities noted for particular students (e.g., getting up to discuss with another student, leaving the room or similar). In addition, general observations were made every few minutes if the activities were unchanged. Where the tape did not record the whole session, the researcher's diary notes were used to determine the activities that occurred in the remainder of the session. This was only required on the following dates, with the journal entries as noted in Table 5.1.

**Table 5.1 – Activities in project sessions not recorded on videotapes**

<b>Date</b>	<b>Time not on tape</b>	<b>Researcher's journal notes</b>
5 March	2.30 pm to 2.45 pm	Groups mostly left, answered a few more questions.
12 March	1.10 pm to 1.35 pm	Opened session with walk to the shed next door ...approximately 20 minutes...Back in N1-12 explained how to resolve the horizontal force into brace members then circulated for consultation. Tape started now.
3 April	1.15 pm to 1.30 pm	Answered questions from pairs.
5 June	12.30 pm to 2.00 pm	Session was completely circulating answering questions to individuals, pairs and small groups and discussion between the students.

A summary table was developed for the lecturer/researcher's activities during the project sessions. Six categories of activities were developed and the total time spent on each activity for each project session, and for the total duration of all project sessions, was then determined by categorising each activity noted in the hand record and adding their durations. In addition, a broad description of the activities in each session was written. The complete data table for this analysis has been included as Appendix C3 with a summary of the outcomes produced in Table 5.2.

**Table 5.2 – Lecturer/Researcher's activities during project sessions**

<b>Activity</b>	<b>Duration (mins:secs)</b>	<b>% of total time</b>
Formal lecture	38:30	5.9
Interactive lecture	126:15	19.4
Working with individuals or small groups	416:45	64.0
Non-contact time (administration, class set-up)	20:30	3.1
Not on tape or recorded in journal	24:00	3.7
Other	25:00	3.8
Total	651:00	100.0

Discrimination between formal and interactive lecture is obviously a subjective issue. The guideline used in the videotape analysis was that a formal lecture period was basically similar to the lecture sessions used within the course, i.e. the lecturer talking to the class, probably using overhead transparencies or similar and with very limited opportunity for student input. An interactive lecture was defined as one that was reasonably impromptu, say in response to a question that several people had asked during consultations. It still involved

the lecturer addressing the class as a whole, but it incorporated multiple opportunities for student questions and comments and was developed as it went along in response to student input.

Analysis of the timeline data summarised in Table 5.2 enables answers to the questions regarding the nature of the sessions and the activities of the lecturer/researcher and students within the sessions to be developed. It is clear that the sessions are different from formal lectures, in that 64% of the time in the sessions is spent by students working individually or in small groups and consulting with the lecturer. For a further 19% of the time students are involved in interactive lectures, and only 6% of the session time was spent in a formal lecture mode. As far as the lecturer/researcher's activities within the sessions is concerned, this translates to 25% of the time being spent standing in front of the class to lecture either formally or interactively, 64% of the time spent interacting with students on an individual or small group basis and the remaining 11% of the time being spent on administrative or other tasks, or not recorded.

These data indicate that the project sessions display several of the characteristics of project-based learning that were discussed in the literature review of Chapter 3, and instructional principles deriving from constructivism detailed in Chapter 1, such as student self-direction, active discussion and engagement of students, teamwork as an integrated part of project work and the teacher's role as a product-oriented supervisor. Hence, to summarise answers to the questions posed earlier in this section – the project sessions were different from formal lectures, the researcher's role was different from normal lecturing and students were active learners during the project sessions.

Regarding the correlation between active participation in the project sessions and good evaluation results for certain students and vice versa, it was decided that there might not have been sufficient data to triangulate successfully for every student in the class. Instead, this has been examined in more detail for five students, four of whom were interviewed. This analysis has been included within the individual student case studies described in Chapter 7.

### **Researcher's journal**

The researcher's journal was used both as a record of events that occurred during the case study and also to record the researcher's thoughts and perceptions on how sessions went, how the class or individual students were progressing and any other relevant matters. Extracts from the journal have already been used as data sources in the discussions above relating to rescheduling and alterations to the lesson plans and observations of what occurred

before or after the videotapes were taken in project sessions, which relate directly to the implemented curriculum. Extracts from the researcher's journal for the same days on which the videotape observation records shown in Appendix C2 were extracted have been included as Appendix C4 as typical examples of the content of the journal.

In general, the researcher's journal provides evidence that the intentions of the curriculum and lesson plans were actually implemented in the project sessions (which can be backed up by the videotape records), and also the lecture sessions (through comparison of journal comments on lecture topics covered compared with the intended lesson plan). Other observations within the researcher's journal have been included within the discussion below, to correlate with student journal observations, and within the discussion of the perceived curriculum in Chapter 6.

One entry made in the researcher's journal on 15 May 2001, towards the end of the course, indicates the value of the projects to both the lecturer/researcher and the students as links between the separate lecture and project sessions.

Interesting to observe that before lectures start many students are discussing their project and often have a question or two to ask...Also have realised that I am able to frequently refer to parts of the project as examples of what I am discussing in lectures and often say "...so in your project you will need to use this for..." i.e. can use the project as an immediate practical illustration of concepts as an additional resource to the worked examples I use in lectures/tutorials. (JM, 15 May)

### **Student journals and email correspondence**

The students in this course had generally not had significant prior exposure to the use of journals, which the researcher was not aware of at the start of the course. It would have been useful to discuss the ideas behind reflective journals and how the students could use them to assist their learning, but there was not sufficient time allowed for this within the project program. Consequently, some of the students just used the journals as a factual record of their progress, what sections of the project they were working on, how long they spent on the project on a given day and comments on which areas they needed to check with other students or the lecturer. However, other students did use the journals in a more reflective way and some of the comments from these journals have been incorporated into the following discussion.

Some journal entries or emails from students provided evidence that specific skills from the list developed for the intended curriculum were being implemented within the case study curriculum. To preserve confidentiality where students have used people's names within their journals, these have been replaced by the person's initials indicated in [ ]. Journal references have been made by providing the student's initials and the date of their entry in the journal in parentheses at the end of the quotation (all journal entries were in the year 2001). Other than this, entries have been reproduced verbatim (spelling and grammar mistakes inclusive, but it should be borne in mind that one third of the students are from non-English speaking backgrounds where English is not the first language at home).

### Technical skills

The implementation and development of understanding of technical skills from the intended curriculum was illustrated by various comments in student journals. Some students recorded the actual content of lectures presented, e.g., "Had lecture for Building for People – went through structures and loads, limit states and factors to consider for design work in structural engineering." (BM1, 26 February). Other journal entries related to one or more of the specific technical skills as per the list in Table 4.3. Whilst it is possible to list the skills as separate items in such a table, in reality many of the skills are intertwined during the design project process. This is illustrated in the following comment from a student demonstrating learning related to the first two technical skills in Table 4.3 – understanding strength, serviceability and stability and understanding loads:

I once again attempted the rafter design, this time with much more success. I was able to do the design of the beam for strength and serviceability with the live and dead loads but when I got to the wind loads I was a bit confused. [JM] said that one of the critical situations was when  $l_e = 6m$  in end wind condition but I don't see how to apply it, as you can see I am confused just talking about it. I need to see [JM] again. (AR, 18 March)

This excerpt also illustrates the student reflecting on their learning process and the iterative nature of knowledge acquisition involved in project-based learning. The same student continued the description of the development of his understanding of loads a couple of days later:

I know that the rafters are exerting a force on the ridge beam but is it in the x or y direction? Do I use a larger member for this application, most probably because whichever way the force is going it will be large. (AR, 20 March)

Although this excerpt is from an early stage in the first project, it already indicates an understanding of load magnitudes and practical applications of the consequences in concept, even if not yet the detail.

Many students checked their understanding of concepts such as loads with the lecturer/researcher in project sessions, in visits to the office or through email before continuing further with their design. The following email is indicative of this: “I have some questions to ask you about the column design. Is it the load acting on the column = rafter + self weight of column + 6 girts (if I design the corner C1 at the 0 degree direction)?” (email from YW on 9 April). Similarly an extract from the researcher’s journal on 30 March gives another typical occurrence as follows:

Questions from [HB/EB] re their rafter design. They had attempted all of the loads and bending moments etc. and wanted to see if on track. They had confused their units with kN instead of kN/m and unsure of how to combine the point load with udl but they had the guts of it there. (JM, 30 March)

The skill required to produce solutions that are functional and economic as well as technically correct was one that was not specifically evaluated through allocation of marks in the projects or examination. However the researcher discussed it at various stages throughout the lectures and project sessions. Some students made comments on these aspects within their journals, indicating that some students achieved some skill acquisition in this area at least, even without formal assessment of it. Comments such as “Indicated section is 75 x 75 x 3 SHS. Believe to be aesthetically flimsy, upgrade to a 100 x 100 x 3 SHS. Question: Is it acceptable to select a larger section for aesthetic purposes?” (NS, 2 April) and “Found that we can use 50 x 50 x 3 EA for cross bracing even though a 25 x 25 x 6 EA is sufficient but impossible to bolt.” (BM2, 2 April) are indicative of students taking functionality into consideration rather than just technical requirements.

Developing a broad knowledge of Australian Standards was another of the technical skills included in the intended curriculum and specified in more detail in the learning objectives of the student course handout. Since Australian Standards are prohibitively expensive, a version that includes the critical sections of the most commonly used standards in structural engineering (including all of those listed in the learning objectives) is produced specifically for student use. This is the document titled HB2.2 mentioned by the students in their journals. Students were required to refer to the standards continually through the design projects, e.g., “Read Chapter 5 (SAA HB2.2 – 1998), Part 2, Design loads on structures: Wind loads Section 3 to gain overview and determine requirements.” (GL, 5 March), and this presented some difficulties – particularly relating to the wind loading code which is

rather poorly written. This was described by EB (5 April) “I think my biggest complaint is the Code, which is not written well in my opinion, bits and pieces everywhere etc., but that is mainly because I have never encountered something like that before”.

Another technical skill component of the intended curriculum was the development of the ability to present engineering data in a professional manner through sketches, drawings and calculations. This skill was allocated specific assessment marks within both projects. Students in the course had a mixed background in this regard. One of the mature age students had over ten years experience with AutoCAD as a design draftsman and others had some workplace exposure to drafting. All students undertook a drawing and drafting course in their first year, but for this student cohort the course had included very little CAD experience. Some students felt that this was difficult to start with:

We both agreed that the project appears to be providing difficulties because we have had no previous exposure to this type of work and therefore we are unsure as to how we set out the structural calculations. It would be useful to have an example to follow. (GL, 20 March)

However, after example calculations were brought to some of the project sessions by the researcher for students to peruse, almost all students presented their final calculations in a professionally acceptable manner. Drawing quality varied more than the calculation presentation and some students found the drawings particularly frustrating. However, they did recognise the importance of developing their drawing skill further, as illustrated by the following student comment:

Drawings is a part of it I really dislike most. Because it is hard to imagine. Besides of that, I need to rub it off when I make some mistakes. At this moment I really hope that I know how to use the CAD drawings, then I can do any corrections on it and print it out. That will be saving my time. So, I decided to pass up our reports and desired to learn how to use CAD drawing tools. (YW, 11 June)

In addition to drawing their own designs, students also needed to develop the skill to interpret drawings from other professionals. The provision of the architectural drawings in the student handout for the second project was intended to start this skill development, as illustrated by the following comment, “Today we got the assignment, looks OK, hopefully this will be a bit easier than the steel design! I just have to have a good look at all of the plans to get more of an idea of what the house looks like.” (EB, 23 April)

## Generic skills

Generic skill development and acquisition also were implemented within the curriculum but in most cases there was no specific assessment or incident that was linked to the generic skills, as most of them were described in the curriculum plan as general throughout the course. However, student journals did give specific illustrations of the development of the generic skills as well as the technical skills. Communication skills were developed partially through the technical communication medium of drawings and calculations discussed earlier, but also through the numerous discussions that took place between students themselves and between students and the researcher. Integrated with the development of communication skills was the development of teamwork and negotiation skills that was illustrated by several students in their journals, for example:

We met again to find that we both are still finding the rafters and ridge beam difficult. I had asked [NS] and some other people for their suggestions but they are also in a mess. We brought all our information together and with the advice from [JM] this week we are planning an extensive effort this weekend. (HB, 30 March)

Did a long session today ... I am pretty happy with it but am a little unsure. Worked with [BM1] and [MT] today and threw ideas around. Overall a very productive day! (NM, 25 March)

These quotations indicated that students collaborated with their partners as well as sharing ideas and discussions across other groups. Contrary to what some faculty might expect, this collaboration did not result in plagiarized work, all students had unique solutions due to the different design decisions they made at various stages of the project, based on their opinions of what was the best solution. (Plagiarised work in design projects is readily identifiable because the numbers determined for critical answers in all projects should be unique due to these differing decisions, so when two projects have the same numbers it is very obvious). Certainly the methodology used by some groups of students in particular sections of the work indicated that they had agreed to adopt the same process amongst a couple of pairs, but their journal entries and the researcher's observations during and outside of class indicated that this was done after debate and discussion, not just copying for expediency without understanding.

Another critical generic skill necessary for professional practice is the ability to undertake problem identification, formulation and solution. Although the project problems in this course were reasonably well defined, there were still opportunities for students to develop



this skill, with further opportunities in subsequent courses. An indication of developing skills in the problem formulation process is given in the following email from a student during the first project:

I believe that the actual process of design is nearly the same as the rafter design which I have already done but I am having some trouble with finding the forces over the beam. Each rafter puts a point load onto the ridge beam which is equal to the load of one rafter as there is two rafters at each point but they only exert half of their load onto the beam while the other half is exerted onto the column. Is that correct so far?... (email from AR, 23 March 2001)

As a consequence of the changing nature of professional practice and training on the job in engineering that has been discussed in previous chapters, the ability for students to develop skills that they will need for lifelong learning, such as independent research skills, self-study strategies is increasingly important. Several students illustrated the development of these skills through the design projects. Journal entries indicate skills such as independent research: “Began to do bracing, the layout & member load determination and tension members design. Kind of having a bit of trouble with this so we went to the library to see if any textbooks could help us nut it out.” (BM1, 5 March); and self-study strategies “Got Warner from library so I could use Warner’s approximation method to determine Slab A depth. Read examples and lecture notes and applied it to the project.” (MT, 4 June) The recognition that they can develop solutions to new problems by referring to other sources as well as revising earlier knowledge when necessary, relying on themselves rather than relying on asking a lecturer, is illustrated by the following student journal entries:

I had a really big day today. Even though I spent a lot of time on the project I didn’t really get much of it done though, it’s probably because I’m always looking in the code, Warner or at the lecture notes. (AR, 29 May)

We can do the analysis for tension and compression but cannot work out the forces in cross bracing. Have to revisit basic structures work. (BM2, 19 March)

Hence, student journals and emails add further evidence to that provided by the researcher’s journal and videotape observations (hence triangulation from three data sources) that the intended curriculum, with respect to student development of the generic and technical skills necessary for professional practice in structural engineering, was implemented.

## Constructivist principles and project-based learning objectives

The foregoing discussion has provided credible evidence that the content of the intended curriculum was implemented within the course in this case study. It is also necessary to determine whether the instructional principles of social constructivism and objectives of project-based learning discussed in Chapters 1 and 3 that were an integral part of the intended curriculum were implemented. Several student journal comments indicate that they were.

The use of industry-based design projects that extend over several weeks of a course satisfies the principles of anchoring learning to authentic, larger tasks that reflect the complexity of the professional environment, thus satisfying three of the constructivist instructional principles developed by Savery and Duffy (1998, refer Chapter 1). Encouraging the students to develop ownership of the problem and solution process are two more of these principles. This was illustrated by numerous students through their commitment to the projects and their sense of achievement when they were completed, e.g. “Fantastic effort – handed it up at 5pm (pulled a 9-5pm again) ⇒ 1 day early” (BM1, 11 April), and “I am most impressed, it’s done!!” (NS, 12 April).

The design projects also encouraged students to test their views against alternative views and contexts, another of the constructivist instructional principles. Much of this was achieved through the discussions and debates that occurred between students (social constructivism) over the best way of proceeding with a task or alternative solution possibilities. These discussions were observed by the researcher in project sessions and noted in the researcher’s journal and student journals. Other students sought advice from external sources and then tested that advice against their own understanding. This was clearly illustrated by one mature age student who works part-time at a firm of consulting engineers:

Sought help in the office for a suitable bracing layout. Office assistance concluded that we use an entire row along the left hand side of the roof. I believe this is incorrect as I have never seen a warehouse with an entire row of cross-bracing along the roof. (BM2, 14 March)

Have a rough idea about serviceability calculations but want a second opinion before I continue. (BM2, 26 March)

The opportunity for students to reflect on both the content and the learning process is the final constructivist instructional principle addressed by the project. The keeping of a journal provided this opportunity for all students, although not all chose to use it in a reflective way. However, those who did recorded reflections on both the content and the learning process.

Quotations such as “We actually got a lot done today, we basically finished the rafters and ridge beams – the methods are correct, which in my opinion is more important than the actual values, but we can change the values when we revise it.” (EB, 9 April) show the student reflecting on the value of learning methods, rather than just getting numerically ‘correct’ answers. Others such as “No major hassles with wind load design, concerned about the generic form of analysis, especially with applying a terrain category without having been on site!!” (NS, 12 March), indicate the student reflecting on some of the shortcomings of the design project (which are also very likely to occur in professional practice).

Many of the objectives and strengths of project-based learning that were discussed in Chapter 3, such as communication and team skills and problem formulation were incorporated into the generic and technical skills of the intended curriculum. It has already been demonstrated in the earlier discussion of this chapter that these skills were implemented in the curriculum of the course in this case study. Project-based learning also develops student initiative and organization skills. Initiative has already been demonstrated in student journal quotations relating to lifelong learning and seeking alternative views. Organisational skills were demonstrated by students referring to their own work schedules in their journals, such as:

We decided to meet at least once a week and ask [JM] as many questions as possible. (HB, 5 March)

Prepare a schedule of the required outstanding tasks and e-mail this information to [SD]. (GL, 8 April)

Met [GL] at City East campus again. We have decided to meet here every week so that the workload is distributed evenly over the semester...Although Slab Panel B seems to be under control, there are many calculations to do and as such I will have to work on this at home. However we are confident that we are on time with the schedule. (SD, 17 May)

The overarching principle for the case study was that of social constructivism, i.e., students developing their own conceptual understanding through the re-evaluation and development of their existing conceptions, in conjunction with the social interaction that took place through small group and class discussions. The critical word in this principle is understanding. For students to develop the technical and generic skills of the intended curriculum that are necessary for professional practice, it is crucial that they understand what they are doing, not just regurgitate methods and numbers. The nature of design projects almost forces students to seek this understanding, because the projects are too complex to be able to muddle along without understanding, although obviously students develop their

understanding at differing levels depending on their ability and interest. In addition, most students become very engaged in projects and don't want to go on to the next stage in a process without understanding what they have done to date. Students stated this very clearly in journal entries:

Cleared up most issues with [JM], however I still need to understand the triangular load case. [JM] suggested using the Three Moment Equation from the notes. Hopefully understanding will come with this calculation method.  
(SD, 28 May)

Students also demonstrated that they had developed sufficient conceptual understanding to assess the reasonableness of their calculations, which is a critical skill for professional practice, as for example, "Also since I finished both the slabs I saw a few errors in CB1, some HUGE numbers. Will fix them next time." (AR, 1 June). Students also did not rely solely on the lecturer to check their understanding, but worked together to achieve this, as illustrated by "Meet tomorrow to go over each other's work to check it and make sure both know what's going on." (LP, 29 May).

On several occasions the researcher reflected in her journal about the development of conceptual understanding of various students and student pairs. This was done after every couple of project sessions and sometimes when students approached the researcher with questions outside of session times. Typical entries included:

Questions from [LP] approximately 10-15 mins. Just wanting to completely understand the bracing. Her questions indicated that she was nearly there and after our discussion I am now confident she has grasped the concept. (JM, 16 March)

[EB] & [HB] – Working consistently, bit behind but very focussed on understanding before progressing so that's fine. [WP] & [SK] – Progressing very well as expected. Questions are always to ensure they have understood the concepts, not "How do we do this?" (JM, 26 March)

From the researcher's perspective the development of understanding was much more noteworthy than whether a correct answer had been achieved.

## Summary

The examination and triangulation of several data sources including the researcher's journal, videotape observations and student journals and email correspondence has demonstrated that

the intended curriculum was implemented within the course in this case study. Technical and generic skill development was included within the project-based component of the course, and the instructional principles of social constructivism that were encouraged were in evidence. The following chapter considers students' perceptions of the curriculum and whether the intended outcomes of the curriculum were actually achieved.

# Chapter 6: The Perceived and Achieved Curricula

## Introduction

This chapter first examines the case study data with respect to student perceptions about the curriculum of the course *Building for People N* and its relevance to professional practice as a structural engineer. The chapter concludes with an analysis of the achievements of the students with respect to the intended and implemented curriculum.

## The Perceived Curriculum

### Introduction

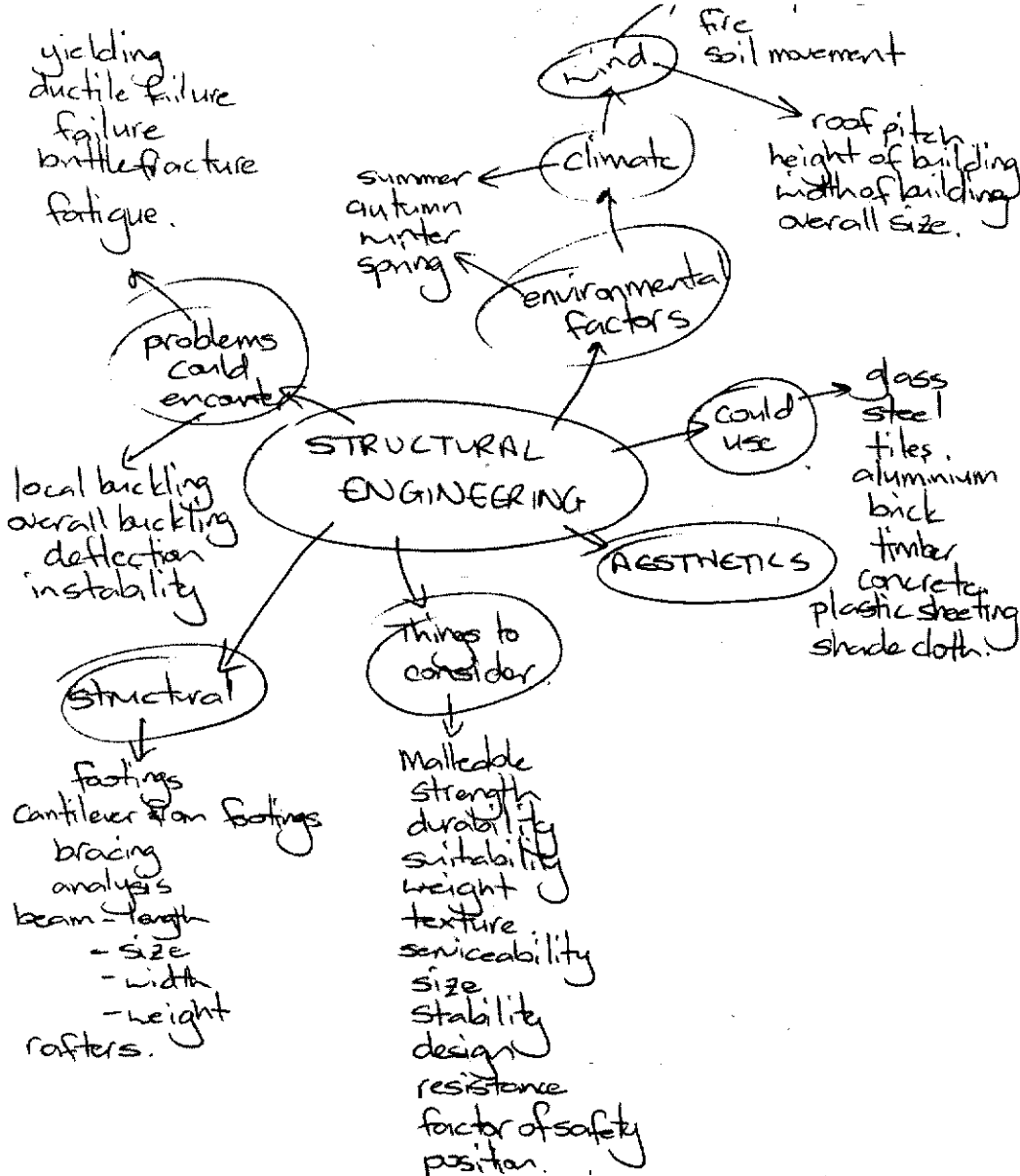
In the previous chapter, the case study data were analysed with regard to the intended and implemented curricula. The analysis indicated that the intended content and methodology of the curriculum was implemented in practice. From the lecturer/researcher's perspective the logical conclusion then becomes that the learning outcomes as indicated in the course handout to students should be achievable. However, it is also necessary to gauge whether the students' perceptions of the curriculum's intentions and learning outcomes are the same as those of the lecturer/researcher. Since the researcher's intention was to use project-based learning because it closely models professional practice, it is important to determine the answer to the third research question: What do students perceive as the relevance of project-based learning to practice?

The primary data sources for student perceptions regarding the curriculum were the Course Evaluation Questionnaire and the Perceived Curriculum Evaluation instrument. Secondary data sources included student journals and emails as well as concept maps. Additional data were gained through student interviews, which are discussed in Chapter 7.

### Concept maps

It was originally intended to ask students to develop a concept map of their understanding of what factors were important to consider in the practice of structural engineering at the commencement of the course, and then compare this with a map they drew at the end of the course. This could have been used to determine whether their perceptions about the practice

of structural engineering had developed through the course. Unfortunately, this could not be implemented in the case study. Students were asked to draw a concept map of structural engineering in their journals at the start of the course, but owing to their unfamiliarity with the development of concept maps and several students not keeping journals during the first project, only one student developed a map. Consequently, there was considered to be little point in asking for a subsequent map at the end of the course. The concept map drawn by the student BM1 is included as Figure 6.1.



**Figure 6.1 – Student (BM1) concept map of structural engineering**

The student’s concept map shows a surprisingly broad understanding of the factors involved in the practice of structural engineering, including material issues, concepts of strength,

serviceability and stability, types of loads to be considered, the consideration of environmental factors and aesthetics. The only major areas missing from the student's map are the importance of economic and construction issues in practice. The concept map was developed shortly after the introductory lecture in the course where students were introduced to limit states design and the concepts of different types of loads. During that lecture, the researcher illustrated the application of this theory by asking the class to brainstorm the tasks and decisions required in the design of a simple residential carport structure, and developed a basic concept map on the board from the class ideas during the session. However, the student's map is considerably more detailed than the example developed in class. Unfortunately for this student, her grasp of the concepts of structural engineering in principle was not matched by her understanding in practice. However, as this map was produced by one of the weaker students in the class, it could be considered to provide some evidence that all students probably entered the course in this case study with at least a reasonable understanding of some of the concepts involved in structural engineering.

### **Student and researcher's journals**

Those students who did use their journals as a reflective tool almost all comment only on the process and their learning in terms of specific aspects or problems within the project. Quotations from these reflections have been used to demonstrate the implemented curriculum. The only reflections made by any students in their journals regarding the relevance of the projects to professional practice were made by two students, who worked as a pair on each project, at the conclusion of the second project:

Project is huge, there is a lot of pages, a lot of work has gone into this design, would it be the same in a consulting office? (FL, 8 June)

Finally, I like to say that this project was pretty good. I am very confident that this project will help me with my exam and for future projects (JP, 12 June)

The only reference in the researcher's journal regarding student perceptions of the value of project-based learning was a comment made during a visit to the researcher's office by student SK to ask some questions. The student said that the project was "where things come together" for them and was "very important". The most useful data on student perceptions was gleaned from the two questionnaires completed by students at the end of the course that are discussed in the following sections of this chapter.



## Course Evaluation Questionnaire

The Course Evaluation Questionnaire was administered to the students during the penultimate week of the course. It consisted of 10 statements that are compulsory for all course evaluations at the University of South Australia, 10 statements selected by the researcher from an allowed set of standard statements issued by the university, and two open-ended optional response questions. Responses to the 20 statements were on a 5-point Likert scale, with 1 being Strongly disagree and 5 being Strongly agree. The option of Not applicable was also available. The Course Evaluation Questionnaire is included as Appendix B8 and class average results for the 20 statements are given in Table 6.1.

The complete set of responses for all students is included as Appendix D1, where students have been assigned a respondent letter that was used to relate their open-ended question responses to the Likert scale responses, since all evaluations were anonymous. A Cronbach alpha analysis, also included in Appendix D1, indicated an acceptable overall reliability for the Course Evaluation Questionnaire of  $\alpha = 0.89$  (a reliable instrument should have a value of  $0.7 \leq \alpha \leq 1.0$ ) (Santos, 1999).

The overall average response for the 20 statements on the Course Evaluation Questionnaire was 4.18, indicating that students were generally satisfied with the course. Those statements with average response scores of 4.4 or higher included “It is clear to me that the assessment methods in this course require me to understand the material that has been presented”, “In this course I have been encouraged to develop my own learning skills” and “I can see the relevance of this course for my degree program.” These statements could be interpreted as supporting the relevance and effectiveness of the project-based approach to learning, since it accounted for 40% of the assessment, 30% of the formal contact time and probably 90% of the non-contact time expected of the students in the course.

Those statements with the lowest average scores of 3.3 and 3.4 were “There was generally enough time to understand the things we have to learn” and “The workload for this course was reasonable given my other study commitments.” This could indicate that the projects placed a high workload on the students, or possibly that the depth of understanding demanded by the project-based approach required more time and work than the students were used to from their previous courses.

**Table 6.1 – Course Evaluation Questionnaire responses (5-point Likert scale, n = 21)**

<b>Course evaluation statement</b>	<b>Average response</b>
44. It was clear what was expected of me in this course	4.1
45. The tasks that I was given to do helped me to achieve the learning objectives of this course	4.2
46. The staff teaching in this course showed a genuine interest in their teaching	4.6
47. The projects were returned in a reasonable amount of time	4.5
48. It is clear to me that the assessment methods in this course require me to understand the material that has been presented	4.6
49. The feedback I received on my work has been constructive and helpful	4.2
50. The teaching staff in this course did their best to help me progress	4.2
51. I was generally able to obtain help when I needed it outside of the regular class hours	4.3
52. The workload for this course was reasonable given my other study commitments	3.4
53. The course enabled me to develop and/or strengthen a number of the qualities of a University of South Australia graduate	4.1
54. There was generally enough time to understand the things we have to learn	3.3
55. The lecturer(s) shows an interest in the students	4.3
56. The teaching methods in this course suit the way I prefer to learn	3.8
57. I can see the relevance of this course for my degree program	4.5
58. The content of the course was consistent with the course outline	4.4
59. In this course I have been encouraged to develop my own learning skills	4.4
60. This course has an appropriate balance between increasing my knowledge and developing my ability to apply that knowledge effectively	4.1
61. The knowledge and skills gained in this course will prepare me well for my future career	4.3
62. The assessment methods in this course enable me to best demonstrate what I have learnt	4.1
63. Overall I am satisfied with the quality of this course	4.1

An alternative way of considering these responses is to group them into relevant categories, similar to those used in the national graduate evaluation questionnaires that are sent to all recent university graduates each year in Australia. Five categories have been selected that are appropriate to this study and each statement, except the last relating to overall satisfaction, has been allocated to a category. The categories, allocated statements, class average responses and Cronbach alpha values for each category are included in Table 6.2.

**Table 6.2 – Course Evaluation Questionnaire responses grouped by category (scores on 5-point Likert scale, n = 21)**

<b>Category</b>	<b>Relevant statement nos. from course evaluation</b>	<b>Average response</b>	<b>Cronbach alpha</b>
Good teaching practice – e.g. clear objectives, lecturer interest and availability, feedback	3, 4, 6, 7, 8, 12, 15	4.4	0.76
Relevant teaching and learning methods	1, 2, 13, 16, 17	4.1	0.64
Relevance to degree program and practice	10, 14, 18	4.3	0.86
Appropriate assessment	5, 19	4.4	0.50
Appropriate workloads	9, 11	3.4	0.61

This analysis indicates more clearly that the students supported the project-based learning approach adopted within the course in this case study (although Cronbach alpha values indicate that the reliability of the results is not high for those categories with only two statements, as would be expected). Given that a response of 4 was Agree and 5 was Strongly Agree with the statement, students indicated that they agreed, tending towards strongly agreed, with the teaching practice and appropriate assessment within the course. In responding to the research question, the data suggest that the students did perceive that the course was relevant to their degree program and to future professional practice. They also agreed that the teaching and learning methods within the course were relevant. As discussed earlier the lowest response, between Neutral (3) and Agree (4) was related to the workload within the course which indicates that students believed it was on the high side, although not actually stating that it was unreasonable. This is a valid response because the workload in this course, and in most third year courses, is recognised by the faculty to be heavy, but that is universal in engineering programs and is one of the reasons they are not easy for students to pass.

The first of the optional open-ended questions included in the instrument was “Which specific aspects of the course have you found most useful for your own learning and why?” Responses to this question were made by 14 of the 21 students. The complete list of responses is provided in Appendix D2, with the student respondent letter and their average response score for the instrument as a whole listed alongside each comment. The design projects were specifically mentioned by nine of these 14 respondents. Some comments referred to the realistic nature of the projects and their application to professional practice including “I have found the project-based learning most useful as it provides a realistic

application of knowledge acquired, and an effective learning regime”, “The way of putting together a professional set of calculations as that which was done in the two major projects” and “Being able to apply most of the work in the real world.” These comments further support the conclusion that students did perceive project-based learning as relevant to professional practice.

Other comments mentioned some of the specific learning objectives or skills of the intended curriculum such as conceptual understanding: “Design project – enables a good concept of knowledge and application to be practiced” and “The projects for design are very practical and help to reinforce the theory. Tutorial problems help to reinforce concepts learned in lectures.” Organisational skills were also mentioned: “Most of the course were tasks to complete at your own rate, which was good for increasing organizational skills” as well as visualising failure mechanisms: “Practicals help ‘visualise failure mechanisms’.”

The second of the open-ended questions on the Course Evaluation Questionnaire asked students to “Please use the space below to comment on any other aspects of the course, including any suggested changes.” Responses were made by 16 of 21 students and these have also been tabulated as part of Appendix D2. Given the nature of the question, the expectation was that any criticisms of the course would be made in response to this question, and this was generally true. Some students commented on more than one aspect of the course.

As mentioned in Chapter 5 regarding the implemented curriculum, there were unfortunately some problems regarding the rescheduling of the column practical so that it occurred before the corresponding lectures were given. Other problems related to the practicals, the lack of availability of, and timely feedback from, the second lecturer in the course (MPR). Comments related to these two issues were made by nine students. Although these problems are being addressed for future presentations of the course, the comments did not provide useful evidence of the student perceptions regarding the value of the projects to future professional practice.

The lack of a site visit, which had been scheduled but unfortunately did not occur due to wet weather delays, as discussed earlier, was also mentioned by two students, one stating that “Site visits in both steel and concrete either early on or later in semester to help visualising the ideas and concepts.” Comments related to workload or the speed of the course were made by five students. They included “Maybe the projects can have less workload” and “At times the course was progressing a little too fast for me to learn and understand the topics.” Partially in response to these comments and the evaluation results, but also as part of an on-

going review of the structural engineering stream in the program, it has been decided that the workload in *Building for People N* will be reduced in future years. From 2002, the course will primarily consist of steel design, with only an introduction to reinforced concrete design. There will still be two projects, one worth 30% on steel design and the other a small project worth 15% on reinforced concrete design. The subsequent course in the following semester will contain more concrete design than previously and a larger concrete design project.

The only other comments that were critical related to insufficient library resources (an unfortunate reality for our school due to financial circumstances) and a complaint from the Fijian student regarding not being put in a group for the project, which was discussed previously in Chapter 4.

Positive comments provided in response to this question came from two students, one stating that “Other than that the rest of the subject is great”, following a comment regarding problems with the practical. The other student endorsed the projects as a learning method, stating:

I thought the project approach was particularly useful. It was well thought out and presented but at the same time required us to really think and forced us to apply what we had learnt.

In summary, the Course Evaluation Questionnaire responses indicated that students were satisfied with the course as a whole, endorsed the project-based approach to teaching and learning and did perceive the projects to be relevant to professional practice. Student concerns related to the perceived workload for the course and some scheduling and performance issues related to the second lecturer in the course.

## **Perceived Curriculum Evaluation**

### **Perceptions of the importance of skills – students and industry**

The second instrument used to ascertain student perceptions about the curriculum in the course in this case study was a questionnaire developed specifically for the study, termed the Perceived Curriculum Evaluation (refer Appendix B9). This was given to the students to complete in the final week of the course. The evaluation contained two components, both of which were based on the lists of generic and technical skills in Table 4.2 and Table 4.3 as developed for the intended curriculum. In the first part of the evaluation, students were asked to rate these skills in response to the statement: “Imagine that immediately following graduation you are employed as a graduate Structural Engineer in the structural design team

of a firm such as Connell Wagner or Ove Arup. How important do you believe the following general skills and attributes (or technical skills and abilities) will be in this position?" The rating scale was from 1 to 5, where 1 was Very unimportant and 5 was Very important. In the second part of the evaluation, students were asked to indicate which parts of the course they felt had given them the opportunity to acquire each skill.

The first part of the evaluation was also administered to the Board members of the Structural College of the Institution of Engineers, Australia to gain an industry perspective on the importance of the various skills. The opening statement in this case was altered to "Imagine that you are responsible for the selection and/or performance evaluation of a Graduate Structural Engineer in your organisation. How important do you believe ...(as for students)?" Responses were received from nine members of the board, one of whom is a university professor whilst the remaining eight are senior structural engineers in consulting engineering or project management firms. Many of the board members are actually responsible for the employment or supervision of graduate engineers within their own firms, so their responses were considered to be very relevant in terms of what industry perceives as the important skills for graduate structural engineers to have when they commence employment.

The resulting data are summarised in Table 6.3 which shows the average Likert scale responses on a 5-point scale (5 = most important) for the three skills ranked highest and those skills ranked significantly low by both the student group and the industry group. The description of the skills has been abbreviated in this table and subsequent tables and figures. Reference to the same skill number in Table 4.2 for generic skills and Table 4.3 for technical skills can be made for the complete description of the skill. It should be noted that the sample sizes were not the same ( $n = 21$  for the student group,  $n = 9$  for the industry group) so a direct comparison of Likert response averages may be misleading. One statistical test that can be used to compare the rankings of items provided by two independent and different sized groups is the Wilcoxon-Mann-Whitney test (Siegel & Castellan, 1988). This test can be used to determine whether there is a significant difference in the rankings assigned by one group compared with the other. An examination of the data using this test at the 5% significance level ( $\alpha = 0.05$ ) indicated significant differences in rankings between the student and industry groups for four of the 10 generic skills and seven of the 11 technical skills. The complete list of responses, the ranking of skills for each group and the Wilcoxon-Mann-Whitney test results has been included as Appendix D3. A Cronbach alpha analysis was also conducted of the reliability of the responses from each group for both the overall instrument and the generic and technical skill sub-groups. These results are summarised in Table 6.4 and indicate acceptable to high reliability in all cases.

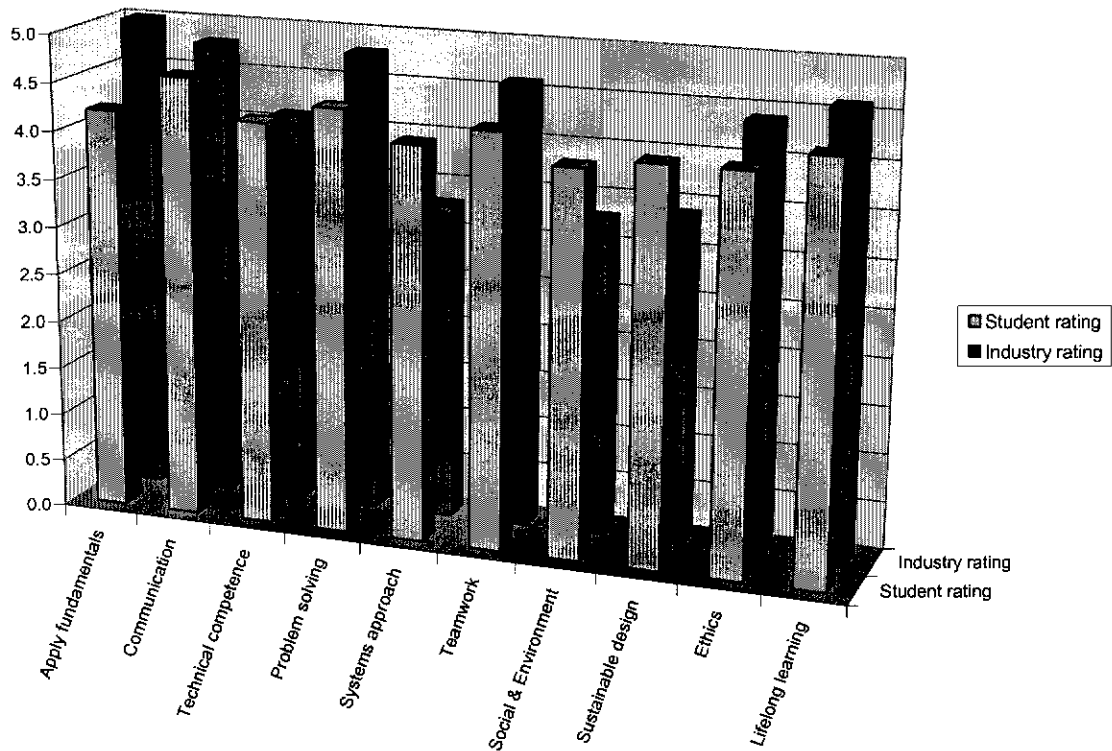
**Table 6.3 – A comparison of the importance of generic and technical skills using the Wilcoxon-Mann-Whitney test based on highest and lowest rated skills as perceived by student group (n = 21) and senior industry group (n = 9)**

<b>Skill</b>	<b>Student response</b>	<b>Industry response</b>	<b>z</b>	<b>p</b>	<b>Significant difference in rank at <math>\alpha = 0.05</math>?</b>
<i>Generic skills</i>					
1. Apply fundamentals.	4.2	5.0	3.24	0.0007	Yes
2. Communication.	4.6	4.8	1.25	0.1056	No
4. Problem solving.	4.4	4.8	1.83	0.0336	Yes
6. Teamwork.	4.3	4.6	1.28	0.1003	No
8. Sustainable design.	4.1	3.4	-1.83	0.0336	Yes
5. Systems approach.	4.1	3.3	-3.22	0.0007	Yes
7. Social & environment.	4.0	3.3	-1.51	0.0655	No
<i>Technical skills</i>					
11. Stability, strength, serviceability.	4.5	5.0	2.14	0.0162	Yes
12. Loads.	4.3	5.0	2.69	0.0036	Yes
16. Visualise failures.	4.1	5.0	3.19	0.0007	Yes
13. Economy.	4.6	4.4	-0.21	0.4168	No
20. Short-cut methods.	3.7	4.6	2.55	0.0055	Yes
19. Computer & design aids.	4.1	3.9	-0.49	0.3121	No

**Table 6.4 – Cronbach alpha analysis results for the Perceived Curriculum Evaluation**

<b>Perceived Curriculum Evaluation component</b>	<b>Student group <math>\alpha</math> values</b>	<b>Industry group <math>\alpha</math> values</b>
Overall	0.88	0.81
Generic skills	0.72	0.73
Technical skills	0.91	0.67

A comparison between the student and industry groups' ratings of importance can be more easily made in graphical form. Figure 6.2 provides a comparison of ratings between the two groups for generic skills and Figure 6.3 provides a comparison for technical skills.



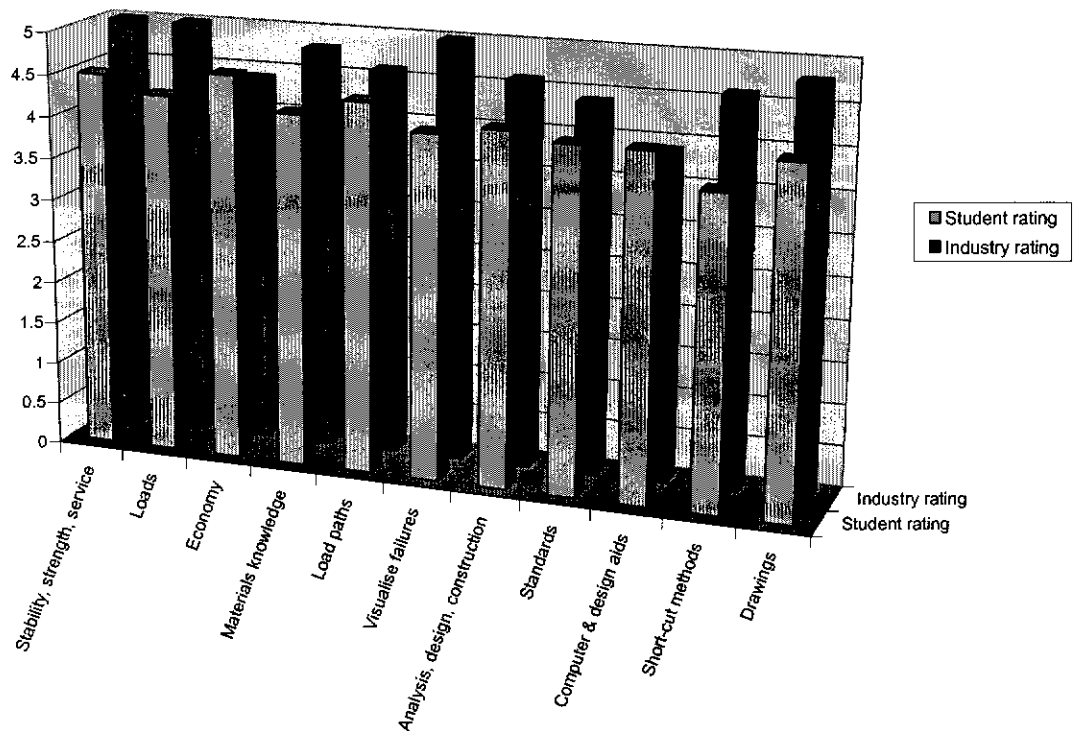
**Figure 6.2 – Comparison of student group (n = 21) and industry group (n = 9) importance ratings for generic skills (5-point Likert scale)**

Close agreement between student and industry responses with regard to generic skills indicated that students had gained a high level of understanding by the completion of the course of those skills that will be important in professional practice as a structural engineer. The most notable difference between student and industry ratings with regard to generic skills was the higher importance placed by students on the green issues of social and environmental responsibility and sustainable design compared with the industry group. The issues of sustainability and environmental responsibility are given particular emphasis throughout the engineering programs at the University of South Australia and this appears to be reflected in the students' response compared with the industry group, even though both groups ranked these two skills as of least importance.

The agreement between the student and industry group ratings was more varied with regard to technical skill importance, which is probably an indication of the relative inexperience of the students in specific technical skills at the time, given that the course was the first of three they would complete in structural engineering before they graduate. With regard to technical skills the greatest difference in ratings between the groups was for the skills related to visualising failure mechanisms and using short-cut methods to check computer program outputs. Neither of these skills was implemented in the course in this case study since they require the use of structural analysis and computing skills that are developed in later courses



in the program. Hence it is not unexpected that the student group did not rate these skills as highly as the industry group.



**Figure 6.3 – Comparison of student group (n = 21) and industry group (n = 9) importance ratings for technical skills (5-point Likert scale)**

The students undertook the questionnaire at the conclusion of the course. The close agreement between their responses and those of the industry group indicate that the students have gained a high level of understanding of those skills that will be important in professional practice as a structural engineer. Since a pre-test was not undertaken, it is not possible to conclude how much of the student’s understanding was gained through the course in the case study in particular and how much from the students’ existing knowledge before they entered the degree program and knowledge gained in subsequent courses prior to the course in the case study.

#### Perceptions of the design projects as a learning opportunity

The second part of the Perceived Curriculum Evaluation given to the students (it was not relevant to the industry group) asked them to indicate from which areas of the course they believed that they had gained the same list of generic and technical skills that they had rated

for importance. The four areas were: lectures/tutorials/practicals; design projects; self-study (other than project work); and no opportunity in the course (see Appendix B9) which have been abbreviated to lectures; projects; self and none in Table 6.5. Students were asked to tick as many boxes as they believed were relevant, in other words they could have up to three ticks if they believed they gained that skill from all areas of the course. The results tabulated in Table 6.5 show, in each column, the percentage of students who ticked that option. (Note that since more than one box could be ticked, the percentages do not add to 100% for each skill). The ranking of each option for each skill has been indicated by the number in parentheses. These data have also been represented graphically in Figures 6.4 and 6.5 for generic and technical skills respectively.

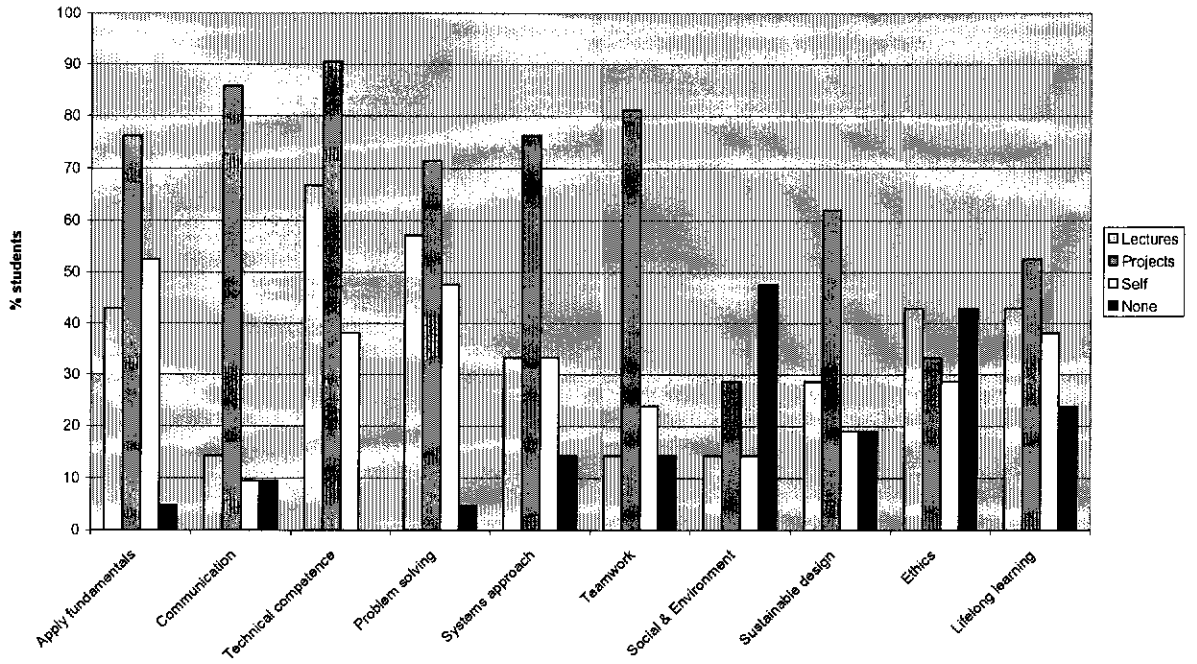
These data indicate strong support for the design projects as the learning opportunity that students perceived was most important in gaining the required generic and technical skills. Design projects were rated as the area where most students perceived that they had gained these skills for 16 of the 21 listed skills, and as the second ranked area for four of the skills, with the last one remaining skill considered to have no opportunity in this course. All of the skills ranked by the industry group and the students as being most important were perceived as being gained most through the design projects. Lectures/tutorials/practicals were generally ranked second most important for most skills, indicating that they are perceived as useful learning experiences by the students.

It is also interesting to note that the students perceived that they learnt additional skills in the course, and particularly the design projects, compared with the researcher's original curriculum plan. In that plan (Refer Appendix B5) the intention was that only generic skills 1 to 4 related to applying basic fundamentals, communication, in-depth technical competence and problem identification would be specifically implemented in the course. However, students perceived that they also gained skills in systems approaches, teamwork, sustainable design and lifelong learning and ranked all of these as being most gained through the design projects. With regard to technical skills, the researcher's curriculum plan did not specifically implement those relating to material properties, alternative load paths and short-cut methods to check computer programs. Students perceived strongly that the projects gave them skills regarding material properties, which could be taken to mean that the design projects reinforced concepts that students had been taught in previous materials courses. Understanding the need for alternative load paths was discussed and illustrated in one lecture using the progressive collapse of floors in the Ronan Point tower disaster in the United Kingdom in 1968 as an example. This visual illustration obviously made an impact, since 67% of students considered that lectures had been their best opportunity to gain this skill.

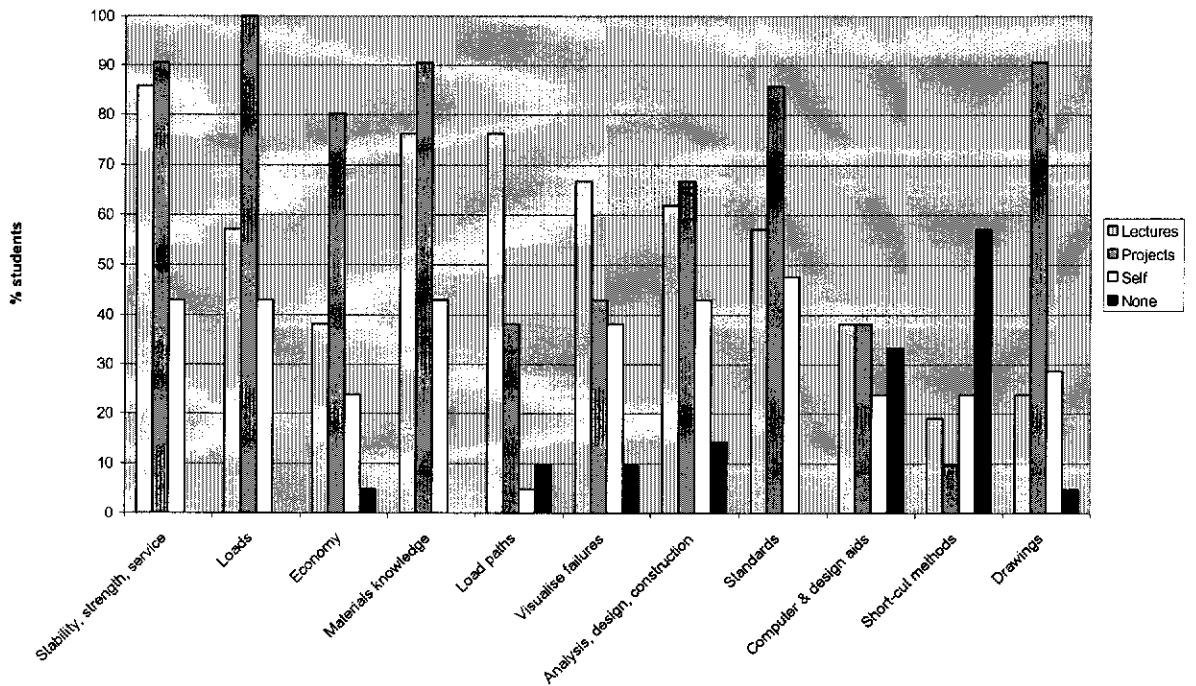
Students agreed that the skill of knowing short-cut methods for checking computer program outputs was not specifically implemented in the course.

**Table 6.5 – Students’ perceptions of opportunities for gaining skills through lectures, projects and self learning during the course**

<b>Skill</b>	<b>Lectures</b>	<b>Projects</b>	<b>Self</b>	<b>None</b>
Generic skills	% students (ranking)	% students (ranking)	% students (ranking)	% students (ranking)
1. Apply fundamentals.	42.9 (3)	76.2 (1)	52.4 (2)	4.8 (4)
2. Communication.	14.3 (2)	85.7 (1)	9.5 (3)	9.5 (3)
3. Technical competence.	66.7 (2)	90.5 (1)	38.1 (3)	0
4. Problem solving.	57.1 (2)	71.4 (1)	47.6 (3)	4.8 (4)
5. Systems approach.	33.3 (2)	76.2 (1)	33.3 (2)	14.3 (4)
6. Teamwork.	14.3 (3)	81.1 (1)	23.8 (2)	14.3 (3)
7. Social and environment.	14.3 (3)	28.6 (2)	14.3 (3)	47.6 (1)
8. Sustainable design.	28.6 (2)	61.9 (1)	19.0 (3)	19.0 (3)
9. Ethics.	42.9 (1)	33.3 (2)	28.6 (3)	42.9 (1)
10. Lifelong learning.	42.9 (2)	52.4 (1)	38.1 (3)	23.8 (4)
Technical skills				
11. Stability, strength, serviceability.	85.7 (2)	90.5 (1)	42.9 (3)	0
12. Loads.	57.1 (2)	100.0 (1)	42.9 (3)	0
13. Economy.	38.1 (2)	80.1 (1)	23.8 (3)	4.8 (4)
14. Materials knowledge.	76.2 (2)	90.5 (1)	42.9 (3)	0
15. Load paths.	76.2 (1)	38.1 (2)	4.8 (4)	9.6 (3)
16. Visualise failures.	66.7 (1)	42.9 (2)	38.1 (3)	9.6 (4)
17. Analysis, design and construction.	61.9 (2)	66.7 (1)	42.9 (3)	14.3 (4)
18. Standards.	57.1 (2)	85.7 (1)	47.6 (3)	0
19. Computer and design aids.	38.1 (1)	38.1 (1)	23.8 (4)	33.3 (3)
20. Short-cut methods.	19.0 (3)	9.6 (4)	23.8 (2)	57.1 (1)
21. Drawings.	23.8 (3)	90.5 (1)	28.6 (2)	4.8 (4)



**Figure 6.4 – Students’ perceptions of opportunities for gaining generic skills through lectures, projects and self learning during the course**



**Figure 6.5 – Students’ perceptions of opportunities for gaining technical skills through lectures, projects and self learning during the course**

## **Summary**

Overall the study has shown that students' perceptions of the generic and technical skills that will be important for successful structural engineering practice agreed closely with those of a senior industry group in that area of engineering. This finding indicates that students had achieved a good understanding of the skills that would be necessary for professional practice by the conclusion of the course in this case study. Students also indicated overwhelmingly that they perceived the design project component of the curriculum in the course in this case study as being the most effective learning method for gaining these skills. In addition, students perceived that the design projects gave them the opportunity to gain more skills than those originally envisioned by the researcher in the curriculum plan. Thus, in answer to the third research question of the study, students perceived that project-based learning is very relevant to professional practice.

## **The Achieved Curriculum**

### **Introduction**

The final research question to be answered is – How effectively do students achieve the intended learning outcomes using a project-based approach? There are some key terms that must be considered in order to answer this question; one is intended learning outcomes. For the purposes of this study, this term is effectively the same as the intended curriculum. Hence it includes both the learning of the generic and technical skills as discussed in the curriculum plan, and also the objectives of project-based learning discussed in Chapter 3 and examined further in Chapter 5, such as initiative, organisation skills and reflective practice.

The other critical term is effectively. How is effectiveness measured? In traditional curricula, effectiveness was measured purely on results in tests or examinations. Some engineering faculty still believe that this is the best way to determine whether the students 'know their stuff'. However, most educational practitioners would dispute this and argue for a variety of assessment methods to enable students to demonstrate their understanding. The difficulties of assessing the effectiveness of project-based learning have been discussed by Heitmann (1996) and Lenschow (1998) and discussed in Chapter 3. The added difficulty of assessing the effectiveness of any initiative in a study in the natural classroom setting has been discussed by Felder (1995), who undertook a longitudinal study of a cohort of students he taught in chemical engineering courses in five consecutive semesters using active and cooperative learning methods:

An intractable problem associated with this study (and with all other educational studies in natural classroom settings) is that positive effects of experimental instructional methods may be due in part to the methods themselves, in part to personal attributes of the instructor, and in part to the Hawthorne effect (wherein doing **anything** differently may effect people positively). Even when the results for the comparison group are available, they will not establish definitively whether any observed between-group differences were due to the experimental instructional methods, and if so, which methods. (p. 10, on-line version)

The American Society of Engineering Education in their Assessment White Paper (ASEE, 1996) discussed the nature and purpose of assessment. Specifically, they examined the question of assessment of engineering students in relation to a list of attributes of the ideal engineering graduate. This is a similar issue to examining how effectively students in this case study developed the generic and technical skills listed in Table 4.2 and Table 4.3.

It is unnecessary to assess the performance of each student to know if engineering graduates from a particular program are generally developing the attributes of an ideal engineering graduate. Stated another way, we should not confuse the ability of the engineering education community to articulate a vision for the ideal graduate as a mandate for every graduate of every engineering program to demonstrate competence and proficiency in every attribute. Each goal is a yardstick against which to measure program success, not an item on a checklist to inventory failure. (p. 3)

These statements indicate that an assessment of the effectiveness of project-based learning in this study should be based on multiple data sources, not just formal assessment of individual student's product and content. Heitmann suggests that assessment of student skills and attitudes must also be considered and that other methods such as review of processes, self-assessment by students, and involvement of external examiners could be used.

Data sources that have been used in this study include the formal assessment results for the course overall and the examination and project components. Within this assessment, marks were also mapped to specific generic and technical skills and these results are discussed below. Within the discussion of the implemented curriculum in Chapter 5, data in the form of quotations from students' journals were used to demonstrate their skill acquisition in areas such as teamwork, organisation skills and reflection. These journal entries combined with the perceptions of students evaluated in the perceived curriculum can be considered as a self-assessment by the students that demonstrates the effectiveness of project-based learning

within the course in this case study. Other data involving self-assessment by students are included in the interviews with students in Chapter 7. External examiners were not involved in the case study. The processes involved within the particular course in the case study were reviewed thoroughly by the researcher, as part of the process of setting up the study. Another form of assessment that would be very informative for this study would be to interview those students (and possibly their supervisors) who eventually enter the field of structural engineering as graduates after they have been in the workforce for a couple of years to examine their perceptions of the effectiveness of project-based learning at that time. However, that will be outside of the time-frame for this study. Hence, several data sources have been used to examine the effectiveness of project-based learning in this case study, but the remaining discussion in this chapter will focus primarily on the formal assessment outcomes.

Even though there are some concerns in using formal assessment results as measures of effectiveness, greater confidence can be placed in these results when they are based on authentic learning tasks that reflect the complexity of professional practice. The National Research Council (1996) has noted this in the context of assessment in science education:

When students are engaged in assessment tasks that are similar in form to tasks in which they will engage in their lives outside the classroom or are similar to the activities of scientists, great confidence can be attached to the data collected. Such assessment tasks are authentic. (p. 83)

Hence, despite the shortcomings of formal assessment as a measure of effectiveness when taken on its own, it is an important component of overall effectiveness, and the authentic nature of project tasks improves the validity of that portion of the assessment in particular. Accordingly, the following sections of the chapter examine the formal assessment results as a contribution to the overall determination of effectiveness of the curriculum.

### **Overall achieved curriculum analysis**

Of the 23 students originally enrolled in the course, 20 completed all requirements for assessment (two students withdrew before completing any assessment and one student did not submit the second project or sit the examination). Of these, 18 achieved a pass mark of 50% or more in the overall assessment and two students failed (47%, 45%). Class average marks for the 20 completing students in the major components of the course are shown in Table 6.6. The complete record of student results (with students identified only by their initials so that correlations with journal comments may be made) is given in Appendix D4.

**Table 6.6 – Class average assessment (n = 20)**

<b>Course component</b>	<b>Marks</b>	<b>Percentage (%)</b>
Steel design project	16.8 / 20	84.0
Concrete design project	16.0 / 20	80.0
Practicals (laboratories)	6.2 / 10	62.0
Steel exam component	10.1 / 20	50.5
Concrete exam component	15.7 / 30	52.3
Overall	64.7 / 100	64.7

These results indicate that students generally achieved much better marks in the design projects than in the examinations. This raises the long-standing debate about the value of examinations versus continuous assessment in evaluating learning outcomes, with supporters of examinations believing that if students can not produce correct solutions under pressure then they can not have learnt the material, while supporters of continuous assessment methods such as projects argue that examinations support surface learning while projects promote deeper learning, which is necessary for professional engineering practice (Felder et al., 2000). However, another factor that also needs to be considered in these results is that students who knew that they had already achieved a near pass from their results in the projects and practicals may have chosen to focus on other courses with higher examination components to maximise their overall success, and not studied particularly hard for the examination in this course. This possibility was not specifically evaluated in the study.

Students certainly have the opportunity to re-visit and upgrade their original solutions during the course of a project as they discuss and compare their outcomes with the lecturer and other students, which is likely to lead to higher assessment results (although this could be considered to be proportional to the effort made by undertaking this review and upgrade process). Projects allow students to assess, discuss and re-work if they have made initial errors. In professional practice the time available for, and costs associated with, re-work would soon lose firms work if it happened to any extent, however, it would be expected that graduate engineers in those firms would go through this process initially until their experience and confidence increased. In practice, projects also will have time constraints or budgets related to the quoted fees, but there will certainly be nothing like the time pressures and stresses that students experience in formal examinations.



## Design project and examination – achieved curriculum analysis

For each of the generic and technical skills that were used to develop the intended curriculum the most relevant formal measure of effective achievement of that skill was determined. For the generic and technical skills originally included in the researcher's curriculum plan, the measures of achievement have been detailed in that plan (Appendix B5). For some skills this then refers to the mapped marking plans for the projects (Appendices B10 & B11) and the examination (Appendix B13). For other skills the measure of achievement was taken to be the area of the course where students perceived they had gained the skill, as indicated by the Perceived Curriculum Evaluation. This was usually the overall project result. Several skills used the same measure of achievement, and effective achievement of some skills was not specifically assessed in the course. Where skills were mapped to specific marks in the project or examination, the project mark sheet and examination script of each student were analysed, and the marks for each skill component totalled to arrive at a score of the possible marks for that skill. The class average of these results for the 20 students who completed the course, converted to a percentage, is given in Table 6.7 for skills measured by the examination or overall results, and in Table 6.8 for skills measured by the design projects.

**Table 6.7 – Class average assessment (n = 20) for generic and technical skills assessed by examination or overall results**

<b>Skill</b>	<b>Assessment measure</b>	<b>Class average (%)</b>
<i>Generic skills</i>		
1. Apply fundamentals	Overall course assessment	64.7
3. Technical competence	Overall course assessment	64.7
4. Problem solving	Mapped to specific marks in exam	51.5
<i>Technical skills</i>		
11. Stability, strength, serviceability	Mapped to specific marks in exam	52.8
12. Loads	Mapped to specific marks in exam	83.5
17. (a) Analysis techniques	Mapped to specific marks in exam	39.2
17. (c) Design	Mapped to specific marks in exam	52.8

A significant point to note from this analysis and an examination of Appendices B10, B11 and B13 is that very few of the generic or technical skills could be mapped to specific marks in formal assessments. For the examination, only one generic skill – problem identification, and three technical skills were specifically examined – the understanding of strength,

serviceability and stability, understanding loads (although only 2.5 marks), and analysis and design techniques (separated into two components in Tables 6.7 and 6.8, but both were part of technical skill 17). It is interesting to note that the examination assessed such a narrow part of the overall curriculum intended and implemented in the course. If this analysis were undertaken in most engineering courses it would not be surprising if similar results were found, i.e., that formal examinations assess very little of the intended curriculum of the course. The projects specifically assessed one further generic skill – communication and two further technical skills – engineering drawings and technical communication. However, the projects overall were considered to be good indicators of achievement in many of the other technical and generic skills as indicated by the perceived curriculum analysis.

**Table 6.8 – Class average assessment (n = 20) for generic and technical skills assessed by design projects**

<b>Skill</b>	<b>Assessment measure</b>	<b>Class average (%)</b>
<i>Generic skills</i>		
2. Communication	Mapped to specific marks in project	79.7
4. Problem solving	Overall results for two projects	81.8
5. Systems approach	Overall results for two projects	81.8
6. Teamwork	Overall results for two projects	81.8
8. Sustainable design	Overall results for two projects	81.8
10. Lifelong learning	Overall results for two projects	81.8
<i>Technical skills</i>		
11. Stability, strength, serviceability	Mapped to specific marks in project	82.1
12. Loads	Mapped to specific marks in project	82.5
17. (b) Analysis techniques	Mapped to specific marks in project	83.1
17. (d) Design	Mapped to specific marks in project	82.1
18. Standards	Overall results for two projects	81.8
21. Drawings	Mapped to specific marks in project	79.7

A direct comparison of achievement for specific skills between the design project and examination components cannot reasonably be made except for technical skills 11 and 17 – the understanding of strength, serviceability and stability and knowledge of analysis and design techniques. The marks mapped for knowledge of design techniques were the same as for strength, serviceability and stability (since design relies on the understanding of these properties) and examination results were approximately 30% lower than design project results for these skills. For the analysis component of technical skill 17, examination results were 44% lower than design project results. However, the examination contained one

analysis question that most students did not attempt. It was noted in the examination paper that students should not attempt the question until they had finished everything else, (refer Appendix B12), with the intention of the question being to allow the highest achieving students in the class the opportunity to gain additional marks needed for a High Distinction. If this is accounted for by viewing the examination results for the analysis component of technical skill 17 in terms of the percentage gained for the marks that were attempted by the student, rather than the total available marks, then the examination results improved to 57% (refer Appendix D5), hence approximately 26% lower than the design project results.

## **Summary**

Formal assessment results taken on their own indicate that students acquired the generic and technical skills more successfully through the design projects than through the examinations. However, formal assessment results alone are not sufficient as measures of effectiveness in project-based learning environments. Other means of assessing student skills and attitudes are also necessary. In this case study, student perceptions and self-assessment as well as process review contributed to the overall assessment of effective student achievement. Comments in the students' journals, interviews with volunteer students and the researcher's observation journal record of questions asked by students during the projects all reinforce the finding that the design projects were the most effective means of achieving deeper and more lasting skill and knowledge acquisition or learning outcomes in the course. The following extract from an interview conducted with a volunteer student after the completion of the course summarises this finding:

Researcher: So you're saying you think you retained the knowledge better than when you just study for exams.

JP: Yes, definitely because it's a long term process, whereas when you study for an exam you sort of cram two weeks and you've got other classes you study for, so you spend like five days on it then you do the exam, and it's gone, finished - whereas for the project you spend ten weeks on it or 8 weeks on it and you work enormous hours on it, like coming in and checking on it so you know what you're doing. Maybe your work may not be 100% correct but you've got a general picture of the procedure. So I mean, I can't even remember what's in the exam, and what questions you gave but if you ask me what the project steps were, I'd tell you step by step.

The conclusion that can be drawn after examining the various data sources used as measures of effectiveness in the case study is that project-based learning was an effective method of

achieving the intended learning outcomes in this course, hence resolving the final research question of the study – How effectively do engineering students achieve the intended learning outcomes using a project-based approach?

# Chapter 7: Individual Student Views

## Introduction

At the commencement of the course in this case study in February 2001, students in the class were informed verbally about the research that the lecturer would be undertaking through the course duration. They were also provided with a written information sheet and call for volunteers asking for students who were willing to be interviewed for the study (refer Appendix B7). Initially seven students returned the signed consent form volunteering to be interviewed. Interviews were conducted at the start of the next semester (July 2001), approximately seven weeks after the completion of the course in the case study. However, two of the students who originally volunteered were not available to be interviewed at that time – one had returned to her home interstate and decided not to re-enrol in second semester due to personal issues and the other did not return from overseas until the second week of the semester. A third student did not respond to a follow-up email regarding suitable interview appointment times, so it was assumed that he did not wish to be interviewed after all.

The intention of the discussion in this chapter is twofold. The first intention is to examine the curriculum implementation, perceptions and effectiveness in more detail from the particular viewpoint of the four students who were interviewed. In addition to the four students who were interviewed, a fifth student is described who was somewhat atypical with regard to participation within the course. The second intention is to use the data gathered from the interviews as additional evidence, for triangulation with the data sources discussed in Chapters 5 and 6, in developing answers to the third and fourth research questions.

## The Students

### Student background

The students to be discussed in this chapter represented a range of backgrounds and achievement levels within the student cohort in the course. Four of the five students are mature age (ranging from 23 to 34 years old). As noted in Chapter 4, nine of the student cohort of 21 in the case study were mature age (i.e., not school leaver) entrants, but all four of the students who were interviewed belonged to this category. This may possibly be a reflection of their greater confidence in being interviewed or maybe greater willingness to assist. A brief description of each student is given below.

SK is a mature age student, aged 25, who came to engineering via the tertiary bridging program. After completing Year 12 with average results in mathematics that were probably not high enough to have given him initial entry to engineering, SK decided to enter his family's landscape gardening business. After three years he decided to pursue tertiary studies in Civil Engineering combined with Environmental Management. He successfully completed the six-month bridging program in 1997 to gain entry to the University of South Australia and commenced the five-year double degree program in 1998. SK's academic record has been outstanding throughout the course, he is almost always the top student in the class, and will certainly gain first class honours. SK is a very hard working and conscientious student who is highly regarded by both students and faculty. He is friendly, articulate and always willing to help other students who ask for assistance. He has also contributed as a student advisor to the review of courses and programs, particularly related to the double degree he is pursuing, because he and two other students in the Building for People course in this case study will be the first graduates from that program at the end of 2002.

GL is another mature age student, aged 34, who was born in Australia but whose home language is Italian. GL completed a Diploma in Civil Engineering after completing high school and has worked as a Design Draftsperson, primarily in the area of sewer and stormwater design, for the past 14 years. GL was actually known personally to the researcher prior to this course because they both worked at the same consulting engineering firm for five years before the researcher came to the university. In 2000 GL decided to return to study to complete a civil engineering degree. He was given credit for approximately half of the program based on his Diploma and work experience and is studying part-time while still working full-time in the engineering department of a local council. GL is granted study leave from work and makes up other hours, but is only able to attend campus on 1.5 days per week. GL is also a very hard working and conscientious student who has achieved excellent results since he entered the degree. He is quiet spoken and reserved and does not know the other students all that well since he is not on campus very often and has classes with different cohorts due to his part-time status.

JP came to the University of South Australia in 2000 from the Northern Territory. He completed a Diploma in Civil Engineering from the Northern Territory University and has worked for a couple of years in the Department of Roads in NT as a soil technician. JP is aged 23. He has been given credit for much of the first two years due to his Diploma and work experience, but has been undertaking Mathematics courses from first and second year along with the later year engineering courses. JP was born in Greece and came to Australia in his childhood, but Greek is still his first language. JP is friendly, outgoing and well liked

by other students. He is honest, hard working and happy to assist others. His academic results have been variable, in the above average range in most engineering courses but lower in the mathematics type courses.

FL is another student who has a Diploma in Civil Engineering, which he completed in 1996 at the University of South Australia. He returned to the University part-time in 1999, after completing three years work experience as a civil technician, to undertake bridging mathematics and physics before gaining entry to the civil engineering degree full-time in 2000. FL did not undertake mathematics after year 11 or complete year 12 at high school, and has had great difficulty with these courses at the university. He has had to repeat one of these courses, and his overall academic record is consequently weakened. However, he has generally recorded average or above average results in the engineering courses within the program. FL was born in Australia of Italian parentage and speaks both languages at home. He is 25 years old. FL is hard working, persistent and happy to help others. During the case study he and JP were partners for both projects and they decided that they would also be interviewed together.

The fifth student to be focussed on in more detail for this chapter is NM. He originally volunteered to be interviewed but did not respond to the follow-up email. NM is somewhat of an enigma to the faculty in the school. He commenced his degree after completing Year 12 at high school and is 21 years old. Although he gained very good Year 12 marks, and is considered by faculty to be bright, he does not attend classes regularly and does not appear to do a lot of work (other students advise that he works considerable hours in part-time employment). He generally passes most classes but does not achieve to his potential. He is still yet to complete the required mathematics components of the course, having failed one course four times because he only completed it once and did not bother to withdraw the other three times. NM is liked by classmates but is not generally well regarded by faculty due to his perceived slack attitude to attendance and required work. He has been included in the discussion for this chapter because he is atypical compared with the students interviewed, in that he did not regularly attend classes or seek assistance from the lecturer during the projects, but did complete a reasonably detailed journal for the first project.

### **Formal assessment outcomes**

The formal assessment outcomes of the five students being discussed in this chapter are detailed in Table 7.1. It can be seen that two of the students, SK and GL, finished first and second, respectively, in the final results of the class. The two students who worked as a pair on both projects, JP and FL, finished with exactly the same final result of 69%, which was

slightly above the class average of 62%. However, they demonstrated different strengths in the examination, with FL doing well in the steel component but very poorly in the concrete and JP just achieving a pass in both components. The student NM achieved only 19 out of 50 for the examination component and had a final passing grade of 56%, slightly below the class average.

**Table 7.1 – Formal assessment results for 5 individual students**

<b>Student</b>	<b>Steel project (20)</b>	<b>Concrete project (20)</b>	<b>Steel exam (20)</b>	<b>Concrete exam (30)</b>	<b>Practical (10)</b>	<b>TOTAL (100)</b>	<b>Comment</b>
SK	18.3	18	19.8	25.7	9.5	91	1 <sup>st</sup> in class
GL	18.3	17.9	18	22	6	82	2 <sup>nd</sup> in class
JP	17.8	19.1	11.3	14.5	6.5	69	
FL	17.8	19.1	16.3	8.2	7.5	69	
NM	17.2	14.7	6	13	5.5	56	

## **The Implemented Curriculum for These Students**

### **Active participation vs. good assessment outcomes**

In the previous chapter, the question was raised regarding the correlation between active participation in the project sessions and good assessment results for certain students and vice versa. This will be examined in more detail for these students.

The five students participated in different ways in the formal and informal components of the course. Attendance at project sessions was recorded by the researcher and on the videotape records. The videotapes of each session have been examined in further detail relating to the specific participation of each of these five students. These observations, along with extracts from the students' and researcher's journal, have been detailed in chronological order through the course for each student and are included as Appendix E2. The sessions attended by each student and relevant comments are summarised in Table 7.2.



**Table 7.2 – Summary of project session attendance**

<b>Student</b>	<b>Steel project sessions attended</b>	<b>Concrete project sessions attended</b>	<b>Comments</b>
SK	March 5, 12, 19, 26, April 3	May 7, 14, 28	SK attended all but the final session of the course (he had already submitted his project before that session).
GL	April 3	May 7	GL could not attend project sessions due to full-time work commitments. We agreed that this was OK since his partner did attend sessions and GL consulted regularly with me on the days he was on campus for lectures.
JP	March 5, April 3	May 7, June 5	JP was undertaking a class that had group meetings that clashed with project sessions in some weeks.
FL	March 5, April 3	May 7, 14, June 5	FL was undertaking a class that had group meetings that clashed with project sessions in some weeks.
NM	March 5, 12, 19	May 28	NM attended sporadically and rarely stayed for the full session

The top student in the class, SK, participated actively in all aspects of the course. He attended all lecture and project sessions (except the final one as noted above). He was also an active participant in the interactive lecture components of project sessions, asking and responding to the researcher's questions, for example on 19 March (refer Appendix E2):

From 6:00 JM gives interactive lecture until 38:00. During this time several questions are posed by JM. Responses are generally from WL, SK and NS. SK is attentive throughout the lecture. After that, several students leave due to a "Rocks" test in the next hour. SK, WL, WP and LE stay to discuss some things on the project then leave by 42:00.

SK also visited the researcher outside of class times to ask questions and clarify approaches as indicated by this extract from the researcher's journal on 24 May (refer Appendix E2):

Questions from some students today. SK was clarifying the use of 3-moment equation including positive moment calculation. Also checking Column C1, first trial indicated neutral axis is above compressive steel, wanted to check that this was OK. (JM, 24 May)

From his overall academic record (GPA approximately 6.6 on a 7-point scale), SK is obviously an exceptional student and has demonstrated that he can achieve well across the

many different content areas and teaching methodologies used in the overall program. However, during his interview, SK referred on more than one occasion to the fact that this particular course suited the way he liked to learn:

It was actually quite good because that, the whole subject, it's going to sound a bit, I'm not trying to sound sucky, but it was geared the way I learn which was really good. We were presented with materials and then it builds you. This is the way I work even if its not around formal tutes and that in a course and then we are able to have practicals and/or the projects which just compound everything you have learnt, especially the projects that you used every bit of the theory that we were taught a week or two previously. That progression of having being taught some theory and then being able to apply it in a real manner, that's the way I learn. (SK, Appendix E3)

Hence for SK, active participation in the project sessions did correlate with high overall achievement, but this was possibly incidental, as the way the course was presented, including the project sessions, clearly suited his individual learning style, and he would undoubtedly still have achieved high formal assessment outcomes. It is interesting to reflect though, that the teaching methodology in the course matches the learning methodology of a very successful student.

In contrast to SK, the other four students were not regular and/or active participants in the project sessions, for varying reasons. As mentioned previously, GL was not able to attend campus on the day that the project sessions were regularly scheduled and negotiated this with the researcher. It was agreed that his partner would attend the sessions and pass on information to GL and that they could consult the researcher on the day that lectures were held, when GL was on campus all day. In addition, GL sometimes telephoned the researcher with further questions. In the two sessions that GL was able to attend, he did not participate actively in terms of asking or responding to questions during class discussions, e.g., "GL does not participate verbally in the informal lecture, but listens attentively. JM consults with GL and SD from 59:20 to 1:02:26 and they remain working when tape ends" (refer Appendix E2). However, that is GL's nature, fairly shy and quiet, amongst groups of people he does not know well. Since GL achieved excellent results in both the examination and the projects (and his examination results were significantly higher than those of his partner, who did attend the project sessions), it was clear that in his case active participation in project sessions was not necessary for high achievement in the course. However, it was certainly the case that GL attended all lecture sessions and participated actively in the project exercise,

meeting regularly with his partner in the evenings at another campus to work on the project, as evidenced in his journal (refer Appendix E2).

The two students JP and FL, who worked together on both projects, were unable to attend several project sessions due to a clash with a mathematics tutorial group meeting during much of the semester. (The clash occurred because both of these students were not doing the standard enrolment schedule and the mathematics meeting had been rescheduled from the original timetable). However, both students attended lectures regularly and participated in class discussions when they were present at project sessions, e.g., from the videotape of the session held on 3 April: "Class opened with a discussion session from 1:30 to 39:50. Questions were answered or asked by SK (4), WL (2), LP (6), NS (4), JP (1), FL (1)." To compensate for missing project sessions, both students came to see the researcher (usually together) on numerous occasions to ask questions and check if they were on the right track, sometimes too often, "Questions on and off all day – especially FL (driving me crazy!). Some are basically just checking they are on track and that their method is correct." (researcher's journal 7 June). They were both enthusiastic and active participants in the project design process, even though they could not attend many class sessions. Similarly to SK, the project approach appeared to suit the learning style of these students, as explained by JP:

I really like that stuff, I really like the way you give us the notes, like every topic for every part of it, you could break a topic into other parts, you had an example for each other part and that's what helped me sort of follow through. I mean it wasn't the way we did it in the project but that was a starting point and for every part in the project that we wanted to design something, especially the concrete part, I used to look at your examples you gave us in class and I looked at the Warner book, other examples and just sort of followed the examples and standards and sort of go on. (JP, Appendix E5)

These students did very well in terms of the project assessment, gaining the highest marks in the class for the reinforced concrete project. They also gained above average overall assessments, but unfortunately their examination results were adversely affected by their focus on the mathematics course they were also undertaking. This is examined in more detail in the discussion on the achieved curriculum below.

The fifth student, NM, was not an active participant in the project sessions. He rarely attended, and when he did he was usually off task and left early (refer Appendix E2). Similarly his attendance rate in lectures was not great and he would often be off task in tutorial periods. There is also no record in the researcher's journal that he ever approached

the researcher with questions about the project outside of class time. His journal records for the first project do however indicate that he was engaging with the project actively and regularly, even though he seems to have preferred to work independently from his partner a lot of the time. However, in NM's case, lack of participation in the project sessions certainly correlated with overall low achievement.

From the very small sample of students examined here, the majority did not demonstrate that active participation in project sessions in particular correlated with high overall achievement. However, the perception that can be gained by examination of the various forms of evidence provided by the videotape observations, student and researcher journal observations, and the student interviews is that active engagement with the project certainly correlated with high achievement in that component of the course. Additionally it seems that the project style of teaching supported the students' preferred style of learning, at least for four of these students.

### **Technical and generic skills**

In Chapter 5, an examination of evidence was conducted with regard to the implementation of the technical and generic skills of the intended curricula. Entries in the journals of these five students illustrated a similar story to those quoted in the earlier chapter, where students demonstrated through the notes and questions they recorded in their journals that skills in relation to loads, Australian standards, strength, serviceability and stability and others were being implemented. Additional evidence regarding the technical and generic skills that were implemented in the course was gained through the interviews conducted with the students, and this is examined below.

The focus sheet used by the researcher to conduct the interviews is included as Appendix E1, and the complete transcripts of the three interviews are included as Appendices E3, E4 and E5. The methodology of the interviews and transcription process was discussed in Chapter 4. The students were all asked, as the opening question of the interview, what they felt had been the critical concepts in the course. The intention of this question was to see how many of the technical and generic skills the students regarded as being implemented in the course, but without any list of these being available to the students. Given that the interviews were conducted six weeks after the submission of the final project, followed by examinations and then holidays, and the open-ended nature of the question, the researcher was not expecting students to be able to recite the course learning objectives but hoped that the principal skills would be recalled.

All students mentioned in varying words the concepts of analysis and design techniques and knowledge of material properties and behaviour in their initial responses. Other concepts of strength, serviceability and strength as well as determining loads also were included in the discussion. From GL:

I feel it was getting the grasp on the practical side of things, on how to analyse complete structures, how practically we analyse a structure, work it out from beginning to end. Rather than have the loads given to us I felt that the main issue there was working it out, working the loads out ourselves. I found it to be very practical in that sense, so that's what I got out of the subject. (GL, Appendix E4)

Another concept mentioned by all students was the use of design codes or Australian standards, although this required prompting from SK, whereupon his response was "Oh of course, yeh that was obvious." (Appendix E3) The skill of presenting calculations and drawings was mentioned by SK "doing reports" but not by the other students. Hence the technical skills that the researcher intended to be implemented, particularly through the projects, as detailed in the original Curriculum Plan (Appendix B5), were those that the students perceived to be the critical concepts presented in the course. This provides further evidence that the intended curriculum was implemented as planned.

The generic skills of the intended curriculum – applying science fundamentals, communication, in-depth technical competence and problem formulation and solution – are somewhat more obscure in nature and were not specifically mentioned by students in those terms in response to this question. However, they are inherent within other statements made during the interviews with regard to applying basic science and engineering fundamentals, such as "...it was the practical follow on from Mechanics & Structures, where you learnt the basic theory..." (SK); "...you need to know stuff from your previous classes like Mechanics & Structures sort of background..." (JP). With respect to problem identification, formulation and solution comments such as "It's not just a question with a right answer, it's how you manipulated the problem and to come up with a reasonable answer, not necessarily the right or wrong one..." (SK) indicated some understanding of this skill. FL described the process of his problem solving in relation to the project in some detail, including the recognition that making mistakes was an important part of the learning process:

It was frustrating at times not knowing, I don't know because sometimes you couldn't exactly find what you were doing anywhere in your tutorials and you couldn't break it, you just couldn't crack the problem and you're thinking oh we'll go this way then you'd be half way through and think no, I'll change my mind now. Sometimes it's very frustrating... But that's just part of the process of learning because if you did go the wrong way you're still learning a lot and think, oh, no, no, I know what I'm doing now, and you'd go back and fix it all, but I mean, that could probably be sorted it out coming in to Uni, ... but it just gets frustrating, I suppose, with any project but you sort of work it out and make sure it's correct and move on. (FL, Appendix E5)

### **Constructivist principles and project-based learning objectives**

The other component of the intended curriculum, apart from the content, was the learning experiences that were intended through project-based learning. These were the instructional principles deriving from social constructivism and project-based learning, including authentic learning tasks, development of communication skills and conceptual understanding through social interaction with peers and the lecturer and examination of alternative views. Evidence for the implementation of these principles, as provided by student journals, videotape observations and the researcher's journal, was examined in Chapter 5. The interviews conducted with students provided additional evidence to support the conclusion that these principles were certainly implemented in the curriculum of the course in this case study.

The principle of anchoring learning to authentic, larger tasks that reflect the complexity of the professional environment was illustrated in the following response from GL:

And it's a lot more interesting because you have got something practical in front of you that you're dealing with and you've got to visualise a little bit more as to what, how this thing's actually put together and how it actually works. Whereas in tutorials or in lectures you tend to only be given the beam and sometimes you don't know how this beam fits or where it fits into an overall structure. So when you've got, when you're dealing with a project, it tends to be something that's more complete, like the shed that we did. You can see all the elements fit in, you can see how they all interact with each other, how the loads are transferred through the system. That's the most important bit, you can see how the loads are transferred through the system whereas you don't really get that in a tutorial or in a lecture situation, so I

think that project work is pretty important. (GL)

Other comments relating to the authenticity of project-based learning have been included in the discussion on the perceived curriculum to follow.

All four students were asked how they felt about working with others during the project and their interactions within the project. All students responded very positively to the fact that they had worked in pairs as well as with other students. GL's response to this question succinctly summarises the principle of social interaction helping to develop student's conceptions and the examination of alternative views:

That's always pretty useful because you get to share knowledge. You get other people's perspectives on various topics and including the lecturer as well. ... With other students we're all in the same situation and some people pick up certain bits better than others and when you just talk about things with other people you get more of an idea of what's actually happening or what the outcome is supposed to be. Sometimes I pick up some things and sometimes somebody else picks up some things and interact a little bit or if you're working in pairs it's always that little bit easier because you're combining information together. (GL)

JP and FL worked particularly well together, but the relationship certainly generated the examination of alternative views as well in the form of lively debate as expressed by JP:

We always double-checked each other's work, most of the time anyway. Apart from that time when we ran out of time and said to each other, if you're happy, I'm happy. Like it's good because you can see where the other person has gone wrong and the other person can see where you have gone wrong and you share your ideas at the moment - we spent hours once arguing about - you're right, I'm wrong, you're right, I'm wrong, but that's part of your - you've got to do that - you've got to disagree and agree or otherwise if you always agree it's no good. (JP)

SK expressed the difficulty that he experiences sometimes in finding someone to work with who is as enthusiastic and of similar calibre to himself at the University, and the strategy that he uses to overcome this:

Working with others is good. I actually had a better working relationship with other people outside of my group pair. So having or knowing someone we can rely on, whether it's your course lecturer or other people that are working with the same calibre as your group it's good. I always struggle with that, with group work, to find someone with the same calibre and not to blow my own trumpet, but it is difficult to find someone as enthusiastic. Certainly I struggled, unfortunately, with my group. But you have to do it and I have worked with other people on other things outside of the University you have to do it, but you find people of the same calibre out there, it is difficult at university. (SK)

Interestingly, in the subsequent course to *Building for People N*, SK teamed up with GL, whom he got to know in *Building for People N*, and they worked extremely well together. SK also expressed the view that group work was an essential part of the process of engineering and the program, and discussed the difficulties that presented for some people:

Having said that too, you probably wouldn't do it if you didn't like working in groups either or not being able to take a role. Some students, especially in a bigger group are very shy and very, I don't know, what it's be - how they think they're going to one day come out of that. It's something they really have to start doing from first year, especially when groups are bigger and you get quite a lot of group work throughout the whole degree, and I think, yeah, you have to be at least active in that to enjoy it. (SK)

Hence the views expressed by the four students who were interviewed supported the earlier evidence from videotapes, student journals and the researcher's journal that the intended curriculum for the course was implemented in the actual teaching of the course, both with respect to the technical and generic skill content as well as the instructional principles of social constructivism and project-based learning.

## **The Perceived Curriculum for These Students**

### **Perceptions of the relevance of projects to professional practice**

The third research question of this study is: What do students perceive as the relevance of project-based learning to practice? In the previous chapter the answer to this question was considered in terms of the evidence provided by concept maps, student journals, the Course Evaluation Questionnaire and particularly the Perceived Curriculum Evaluation. Interviews



with the four students provided further support to the finding of the previous chapter that students perceived that project-based learning was very relevant to professional practice.

...all the projects we have been doing always have been sort of real, sort of things like a two storey house and doing one for Engineering for Urban Living now. Designing box gutters and all that sort of stuff, using a real place and so, yeah, I think they're quite effective because it's what you're pretty much going to be doing when you're working as well, sort of thing, so it's gonna sort of be similar. (FL)

They did also recognise, however, that some simplifications were necessary to enable the projects to be completed by students at their stage of the program, but the fact that they recognised these limitations, and knew that additional steps may be necessary in practice, provided further evidence that their understanding of professional practice had been developed through the course. For example, JP discussed this in relation to the steel shed design project:

I still think for myself that I'm not really - like in the design projects you let us get away with a lot of things or like you said, just take it slow or take that where if we had to work out other things like the load on the purlins that act on the steel battens, and the colorbond sheetings and all that, that would have been a bit more hard for us ... (JP)

SK expressed similar views:

Yes, I don't think they were too superficial. And too, they can't be too ambitious, at this stage of the game they have to be fairly simple and I think they were reasonable. For instance the last one, a two storey house, that had all the plans, you feel like you're doing it for someone anyway, you had all the plans which - whether you used them or not, probably used one or two of them, but to have the bunch of plans, sort through them to look at, it is something that is quite realistic. They didn't seem superficial or false. (SK)

GL was particularly supportive of the use of projects at the university as preparation for professional practice. Given that he has worked within the civil engineering profession for 14 years at para-professional level, his opinion could be considered to carry additional weight:

One thing that I find very positive about this University is that it is very practical and if you apply projects in all subjects, when people go out in the real world, so to speak, they have got a better knowledge because they have already dealt with projects which are real life situations. So I think projects definitely apply to all subjects whether it's drainage, structural or any other sort of engineering area, soils, anything. (GL)

### **Perceptions of the design projects as a learning opportunity**

The Perceived Curriculum Evaluation outcomes discussed in Chapter 6 indicated that students strongly perceived that the design projects provided the learning opportunity where they most gained the technical and generic skills of the intended curriculum. Responses to the course evaluation question on “Which specific aspects of the course have you found most useful for your own learning and why?” also indicated strong support for the design projects as a learning opportunity. Since the responses to the Course Evaluation Questionnaire and the Perceived Curriculum Evaluation were anonymous, it is not possible to directly correlate the comments of the students who were interviewed with their responses to those questionnaires. However, the student interview comments expanded on the nature of the learning they gained from the projects, and also discussed in more detail the way that the projects helped them to integrate the knowledge gained from the other components of the course, i.e. lectures, tutorials and practicals. Several aspects of the project-based learning experience were examined in the interviews and these are considered in turn in the following discussion.

### **Opportunities for meaningful learning**

All of the students interviewed were asked a question about what methods or aspects within the course gave them opportunities for meaningful learning, learning that helped them to understand. The response from all students, in varying words, was that it was the way the course was taught as a whole that was important, with the project as the integration of the theory being given in the lectures and tutorials. Put succinctly by JP “... the project is what puts everything together. It's your general knowledge and what you learn in class.” SK's full response to this question was quoted earlier in the discussion about how the course presentation suited his learning style, but included comments such as “... the projects which just compound everything you have learnt, especially the projects that you used every bit of the theory that we were taught a week or two previously.” GL explained how he used all of the lectures, tutorials and the project to build his knowledge:

Firstly, tutorials are really good because you learn all the theory that you pick up in class, what goes on, what's taught in class, you get a little bit of practice at it. So that's really good and of course at the end of the year you can go through all of those for practice to restrengthen the methods used. And secondly doing the project, I found, strengthened that even further because then you can see how all these little bits that you do in tutorials fit in one complete structure, which is what we do in the industrial shed. So the project was good from a real practical point of view and it was interesting because you could see how it was all coming together and it tended to follow pretty much what we learned every week in the lectures. (GL)

A very similar view was expressed by FL, who used the projects to strengthen his understanding of theory from lectures:

The way that you taught us was pretty effective. Each week or each two weeks or whatever it was, we had to get to a certain point with the project and sort of you were lecturing us on the material that we were meant to be keeping up with sort of thing, so you were effectively teaching us what we were meant to be doing and applying it to the project. And there was only - sort of - you'd only understand it if you went away and worked on the project and you'd get stuck and come and see you, or something. There were a lot of areas that you could make different mistakes in so it's pretty tricky in that sense. But the way we did it was quite alright, with lectures and then work away at your own pace and try and keep up. I mean I don't know how else you could do - teach that I mean. (FL)

Importantly the projects were able to provide not only an opportunity for integration of knowledge for students, but also some challenge for students, including an outstanding student like SK, who describes the limitation of smaller assignments compared with larger projects:

I think they're good and like this project was probably good precursors of what we should be moving towards, especially in final year. So in that sense I think it is good and it's probably a nicer change from just having assignments. For instance, tutes in Soils and Rocks you get seven assignments, nothing that is really project orientated, whereas with the projects you have a bit more flexibility too than an assignment would. It's not so much right and wrong as far as experimenting and with design and being able to put a bit more thought into it - a bit more of your own ideas. (SK)

## Workload

One of the concerns felt by the researcher was that the projects meant that the workload in the course may have been too high. Responses to the Course Evaluation Questionnaire discussed in Chapter 6 did indicate that this was the aspect of the course with which students were least satisfied. However the results were still in the satisfactory range of 3 or higher. The students interviewed agreed that the workload was possibly higher than other courses, but felt that it was still reasonable:

It was all right, I don't think it was too extreme. I think it was reasonable, it was pretty much on par with work we had to do compared with other subjects but I don't think it was too much. It was demanding, but I don't think it was too much to ask especially at this stage of the game. It was pretty good. Keep the pressure up. (SK)

At times it was like a lot of work but looking back on it now that I've completed the whole thing it probably wasn't a lot, but at the time it seems a lot because it's all new and we have to do some self learning. I felt during the course of the project, so, because of the self learning component and trying to think about how to do things it takes a little bit longer so that puts the pressure on a little bit. (GL)

FL and JP mentioned during discussion that they did spend a lot of hours on the project but did not mention that they felt the workload was too heavy. An important consideration with regard to workload is that all people are less likely to view things as too much work if they are genuinely interested in what they are doing, maybe even enjoying it as mentioned by FL:

I think projects are a good way to summarise subjects because especially if you're enjoying it, you enjoy doing the project, you enjoy the subject sort of thing, you're learning things and then you apply them...(FL)

Students were also asked specifically what they felt the cons of the projects were, and it was expected that workload may be mentioned here. However, all of the students interviewed felt that there were no adverse aspects of the projects – that they were challenging and demanding, but that was a good thing.

## Use of projects on their own

The students interviewed were unanimous in their response to the question “Do you think that you could learn using projects alone?” They were all adamant that this would not be possible and that you needed some theory or “body of knowledge” before you could start:

No, I don't think so. The projects sort of take the tutorials and lectures and sort of go further with them. There's just too much to cover in the projects and you'd need a bit of background knowledge for just sort of reading the projects... But as far as working some of that stuff out on your own, or just picking it up and thinking you can do it - I don't think so, because we had a hard time with the tutorials and the lectures, trying to do the projects, I don't see how anybody could just do the project. (FL)

Yeh definitely, I agree that you've got to have the knowledge beforehand, cause if you just walked in there it's like a big cloud and you don't know what is going on ... It's just not the way to get the experience but if you - you have to have like the theory before you can do the practical (JP)

No I think you really need tutes. You need to get concepts from a lecturer and you need to get all the theory behind it. The project on its own would probably be pretty difficult because if - people might find it daunting. I know I would if I saw the complete structure and I'd just had to learn based from that ... so I think the project really strengthens what you learn in your tutorials and your lectures because it puts everything together and you've got a complete project. And also I think it's more interesting too because you have got something in front of you rather than bits of pieces, like what you get out of a lectures and the tutes. (GL)

SK did recognise that learning with projects alone would occur within the final year of the program to come, but that this was based on knowledge acquired in earlier years:

I couldn't see that because, I mean, you need something, you need some basis for us to go on with. I mean you need some body of knowledge to base your project on. Unless it's something that already you've picked up maybe throughout the course this is more like the final year kind of project that's a subject. (SK)

Hence the student viewpoints reflected those of several authors referred to in Chapter 3 and also the practice in project-based engineering programs such as the one at Aalborg University. That is, that project-based learning in engineering is best implemented as a progression, with theory-based courses or components of courses being a necessary part of project-based courses and programs, whilst also recognising that the need for this decreases as the student's body of knowledge increases. Hence final year projects that do not have a theory through lectures component are a realistic expectation.

## Use of projects in other courses

The students interviewed were also unanimous in their responses to the question “Do you think projects are only suited to Structural subjects or can they be used in all subjects? All four students believed that projects could and should be used in other areas as well as structural engineering courses, e.g. “Projects can be used in all subjects, it’s a good way to summarise everything you have learnt.” (FL) However, FL’s parting comment at the end of the interview, although lighthearted, “Too many projects this semester though!” points to the need for coordination between course lecturers to ensure that students are not overloaded. One means of coordination could be to use combined projects across courses, as suggested by SK:

No, not at all, I think they can be used everywhere, in all of engineering, that’s what it is, that’s what it’s about, projects solving the problems. I guess what I’d like to see more of though is not just concentrated on structures, maybe to superficially create some kind of liaison with other groups or for instance environmental things we did a little bit of. Because that’s where I think it’s at as well - Civil and structural, bit of cross-pollinating, so to speak, get a bit of that going on, having to deal with other people.(SK)

This did occur in an earlier version of the *Building for People N* course when a combined project with structural and geotechnical engineering was undertaken, but difficulties were experienced in choosing a combined project that was suited to the level of knowledge of the students in both areas, as well as coordinating the timing between the two lecturers involved. Subsequent program reorganisation made it impossible to continue the approach. However, the final year project at the University of South Australia is a combined project across all areas of the civil engineering curriculum.

## The Achieved Curriculum for These Students

### Formal assessment components

The formal assessment outcomes of the five students were detailed in Table 7.1 and discussed briefly in the introduction. However, they will be considered in more detail here. As already discussed in Chapter 6 though, formal assessment outcomes provide only one part of the answer to the fourth research question of the study: How effectively do students achieve the intended learning outcomes using a project-based approach?

SK was the only student in the course who achieved basically the same results across all aspects of the course, all at about 90%. The next closest to this was GL who achieved 91% in the projects and 80% in the examination. All other students in the class including the other three students considered in this chapter achieved much better results in the projects than the examination.

The assessment for FL in the concrete examination needs some further explanation. FL is a very methodical person who works slowly and steadily. Consequently, he frequently does poorly in examinations because he does not finish them. This also happened in this course. He attempted the steel questions first and gained 16.3/20 or 82% in that component. He then almost completed Questions 3 (a) and (b) of the concrete section, gaining 8 marks of 12.5 possible or 64% for the attempted concrete questions, but then did not attempt parts (c), (d) or (e) worth 17.5 marks, consequently his overall result was 27% for the concrete component of the examination. If the examination had not been time limited, FL's final assessment would certainly have been better, based on the understanding he demonstrated through his project and questions to the researcher.

A similar observation can be made regarding JP who did not complete the parts (d) or (e) of the concrete examination question either. In addition, for FL and JP, their primary focus in that semester was to pass the mathematics course they still had outstanding. The examination for that course was held the day before the one for *Building for People N*. Both students admitted to the lecturer in discussions after the examination that they had focussed primarily on the mathematics, relying on their understanding from the design projects to get them through the *Building for People N* examination. That, combined with cramming for most of the 24 hours between the mathematics and *Building for People N* examinations with almost no sleep, meant that their performance in the examination was not really representative of their ability in the course. They were both disappointed with their examination results, but remained confident that they had learned through the projects and would be able to apply the knowledge again:

But we worked all semester on it so we knew it, so it was fresh still in our heads, I mean even now you could get me to do a similar project and I'd have no problem with it, especially with the concrete... (JP)

The formal assessment results of the fifth student, NM, probably accurately reflect the extent of his engagement with the course. His overall achievement results were fairly poor with his examination component being very weak (38%). One suspects that his fairly good marks in the projects (64% overall) may have been strongly influenced by his partner, AR, who achieved much better examination results (67%) and was very active in regular discussions

and questions with the researcher. Not surprisingly, AR elected to work with a different partner for the projects in the subsequent structural engineering course in the following semester and NM worked alone.

## **Summary**

A study of the particular experiences and perceptions of five students has been carried out in this chapter through examination of the videotaped project sessions in relation to these students, as well as the students' and researcher's journals. Four of these students were also interviewed to gain greater insight into their perceptions. The interview responses provided additional evidence that strongly supported the findings from the previous chapters with regard to the implemented, perceived and achieved curriculum aspects. A more complete picture was obtained of the importance of all of the learning aspects of the course in this case study, with the projects described as the opportunity for bringing together and developing understanding of the theory provided through lectures and tutorials. All of the critical technical and generic skills were considered to be critical concepts of the course by the students, and other comments reflected the implementation of the instructional principles of social constructivism and project-based learning. The students strongly supported the relationship between projects and professional practice and the essential nature of projects to engineering was summarised succinctly by SK in response to the question "What do you think the cons of the project are?"

That's kind of an interesting question because I don't know if you could be an engineer if you thought there were too many cons about project work.... They are good things, I don't know if you'd really be an engineer if you didn't like projects. (SK)



# Chapter 8 – Results and Discussion

## Introduction

The original premise behind this study was that the traditional approach to education in all branches of engineering, involving lecture-based delivery of theory with tutorial or homework problems intended to provide problem-solving expertise to apply the theory, does not provide students with an effective means of learning the skills that they will need for professional practice. This premise has been demonstrated through the concerns expressed in numerous publications by professional engineers and engineering organisations as well as several reviews of engineering education in different countries, which were examined in the review of literature in Chapters 2 and 3.

The specific focus of this study was the discipline of structural engineering education, a specialist area within the broad field of civil engineering. An alternative approach to structural engineering education was proposed, involving the use of design projects, with significant assessment weighting, integrated with lectures and tutorials. It was postulated that design projects in structural engineering model industrial practice and enable students to synthesise the areas of structural analysis, material behaviour and availability, constructability and economics, as required in the professional practice of structural engineering.

In order to examine the effectiveness of project-based learning in structural engineering, a case study was conducted by the researcher in a third year undergraduate structural engineering course, *Building for People N*, at the University of South Australia in first semester, 2001. A model for curriculum evaluation developed for science education was applied to the course in this case study. The model involved examination of the intended, implemented, perceived and achieved stages of the curriculum. The theoretical framework used to implement and evaluate the curriculum was that of social constructivism. This framework involves students constructing their own understanding through modifying their originally held concepts of knowledge in an area, when they believe that they find viable alternatives or modifications of those concepts. These viable alternatives are not just presented by a lecturer, but are negotiated and examined through the social interactions that take place in a constructivist learning environment. The learning environment of project-based learning is one that puts into place many of the instructional principles of social constructivism. Multiple sources of data, including the researcher's journal and observations,

student journals, videotape observations of project sessions and student evaluation questionnaires, were collected, analysed and compared (triangulated) to develop responses to the research questions.

This chapter summarises the findings of the study and discusses their significance with respect to the future use of project-based learning for structural engineering education. The extension of the curriculum evaluation model used in the study to other areas of engineering and to engineering programs as a whole, rather than individual courses, is discussed. In addition the possibility of using this model for program accreditation requirements will be examined. Finally, the expansion of the use of project-based learning into all areas of engineering education is considered, including some of the difficulties and key issues that need to be addressed for this to occur.

## **Research Findings**

The responses to each of the four research questions are summarised in this discussion.

### **Research question 1**

What do students of structural engineering need to learn in order to be able to design/construct engineering structures when they enter professional practice?

The response to this question was developed primarily through an examination of the literature. This included discussions by industry practitioners of the skills and abilities needed in engineering graduates, reviews of engineering education that had been conducted in Australia, the USA, the UK and other countries and the accreditation requirements of both engineering education organisations and professional registration bodies. In addition, the professional experience of the researcher gained through 15 years of industrial practice prior to entering academia and the input of senior engineers who make up the Board of the College of Structural Engineers of the Institution of Engineers, Australia was also utilised. After consideration of these inputs, the response to research question 1 that was adopted for this study was a set of 10 generic and 11 technical skills necessary for professional practice as a structural engineer, and these were listed in Table 4.2 and Table 4.3. The technical skill list was based largely on the guidelines for assessing membership of the Structural College of the Institution of Engineers, Australia (IE Aust, 2000). These guidelines were very similar to those used by the Institution of Structural Engineers in the UK (IStructE, 2000). The generic skills list was based on the accreditation guidelines for university engineering courses developed by the Institution of Engineers, Australia, (IE Aust, 1999) which were

also very similar to those of the ABET accreditation requirements for engineering programs in the USA (ABET, 1999).

The list of generic and technical skills was then used to develop the intended curriculum for the course in this case study. Not all skills were implemented within the course, some were implied but not assessed, some were included in previous or subsequent courses, but the curriculum plan specifically included most of the skills from the list to be implemented in the course. The implementation was intended to be primarily through the two design projects within the course, but this was integrated with lectures, tutorials and practicals for several skills. The intended curriculum was articulated to the students through the Learning objectives that were included in the Course handout (Appendix B1) given to students and discussed in the opening lecture of the course.

The other component of the intended curriculum for the course in this case study, apart from the content that was guided by the skills list, was the way in which the course would be taught. This was guided by the set of instructional principles for social constructivism that was developed by Savery and Duffy (1998), as discussed in Chapter 1. The use of project-based learning, with students working formally in pairs and informally in their own small study groups or during informal class project sessions, designing realistic structures of reasonable complexity and with no correct answer to the problem inherently satisfies these instructional principles.

## **Research question 2**

How can these learning requirements be implemented through a project-based curriculum?

The response to this question must be two-fold, firstly, how did the researcher plan to implement these learning requirements through the project-based curriculum, and secondly, did this implementation occur?

The researcher's plan for implementation with respect to the content of the curriculum, i.e., the list of generic and technical skills, was detailed in the curriculum plan and lesson plan developed during the planning of the course (Appendices B5 and B6). The intention was to implement four of the ten generic skills specifically through the projects, with two of these also to be implemented through the rest of the course (lectures, tutorials) as well. Eight of the eleven technical skills also were to be implemented, with the majority of these specifically implemented and assessed within the projects. The exact nature of the implementation is described in the curriculum plan. The second component of the learning requirements, that of developing student concepts and understanding through a learning

environment that modelled social constructivist principles, was implemented almost entirely through the design projects. The lectures, tutorials and practicals were timetabled and structured such that they were complementary components to the main thrust of the course, which was the undertaking of two realistic design projects. Although the formal contact time in the course was only about 30% devoted to project sessions, the student learning outside of formal contact hours was intended to be almost entirely through the design projects, by requiring students to apply the theory provided in lectures and tutorials to their projects. It was also intended that much of this learning would take place through the social interaction and negotiated understandings developed by students through working in pairs on the project, as well as through the informal study groups that developed. Hence the response to the research question regarding the intended practical implementation of the learning requirements revolved around careful planning of the curriculum, such that the learning content as well as the desired learning environment were both integral parts of the design project basis of the course.

The second critical part of the response to research question 2 was whether the intended implementation happened in practice. The response to this issue was determined through the examination and comparison of data from several sources that included the researcher's journal, student journals and email correspondence and the observations from videotapes made of all but one of the design project class sessions. These data clearly indicated that the generic and technical skills content intended for the course were implemented, in practice, through the questions and issues that students endeavoured to solve for the design projects. In addition, the implementation of the instructional principles of social constructivism through the design projects was clearly illustrated within these data, through comments or observations relating to students' ownership of the problem, the examination of alternative views and negotiated agreements, reflection on the content and learning process and the authentic nature of the project tasks. This was made particularly clear from the final data source examined, which was the responses of four students who were interviewed after the conclusion of the course.

Hence, the course in this case study provided an example of how the learning requirements developed in response to the first research question can be implemented through a project-based curriculum, thus illustrating a response to the second research question.

### **Research question 3**

What do engineering students perceive as the relevance of project-based learning to the professional practice of structural engineering?

A response to this research question was developed by examining and comparing several sources of data from the case study, including student journals, emails and interviews and particularly two evaluation instruments – the Course Evaluation Questionnaire and the Perceived Curriculum Evaluation. The latter questionnaire also was answered by members of the board of the Structural College of the Institution of Engineers, Australia to compare the perceptions of a senior industry group with those of the students. The questionnaire results and other data indicated that the students developed a good understanding of the technical and generic skills necessary for the professional practice of structural engineering, which agreed closely with the understanding of the industry group. The students also indicated that they perceived that they had gained additional skills, other than those originally envisioned by the researcher in the curriculum plan for the course (refer Table 6.5). Students also indicated overwhelmingly that they perceived the design project component of the curriculum as being the most effective learning component for gaining both the originally intended and the additionally perceived skills. This was further reinforced by the responses of the four students who were interviewed.

Thus, in response to the third research question of the study, students clearly perceive that project-based learning is very relevant to the professional practice of structural engineering.

#### **Research question 4**

How effectively do engineering students achieve the intended learning outcomes using a project-based approach?

The final research question of the study is the most difficult to answer because of the subjective nature of any assessment of learning outcomes, whether it be through formal assessments such as examinations or through more informal means. The intended learning outcomes in this study were taken to be effectively the same as the intended curriculum, i.e., both the learning of the generic and technical skills as discussed in the curriculum plan, and also the development of students' knowledge through initiative, negotiated understandings, communication skills, organisation skills, reflective practice and other aspects that are an integral part of project-based learning.

The determination of effective achievement of these skills was undertaken through a mixture of quantitative and qualitative assessment measures. These measures included formal examination results and formal project design results, both of which included mark components that were mapped to specific technical and generic skills. However, the formal examinations and even the mapped project marks could only be used to assess a fairly narrow range of skill acquisition. The authentic nature of the design project tasks does,

however, provide greater confidence in the formal assessment outcomes gained from such a task. The formal assessment results in the course, taken on their own, do clearly indicate that students acquired the generic and technical skills more successfully through the design projects than through the examinations.

However, formal assessment results are not sufficient measures of effectiveness in project-based learning environments; other means of assessing student skills and attitudes are also necessary. In this case study, student perceptions and self-assessment as well as process review contributed to the overall assessment of effective student achievement. Comments in the students' journals, and the researcher's journal record of questions asked by students during the projects, reinforced the finding that the design projects were the most effective means of achieving deeper and more lasting skill and knowledge acquisition or learning outcomes in the course. Student interview comments about the depth of understanding gained and retained through doing the design projects, compared with the common practice of cramming for examinations then forgetting everything, provided particularly strong support for the effectiveness of project-based learning.

Hence, the response to research question 4, based on the data obtained through this case study is very effectively. This then raises questions about the significance of this finding. If it works in this case, can it be applied to other courses, other programs, other institutions? How dependent were these findings on the particular background or skills of the researcher who instituted the case study and taught the course? Could the model used to assess the curriculum outcomes in this case study be applied in other situations? What are the issues that must be considered if the use of project-based learning was to be extended in engineering? An examination of these questions and some possible answers forms the concluding discussion of this research study.

## **Significance and Limitations of the Findings**

### **Significance**

There are several findings of significance from this case study. Probably of most significance is the finding that project-based learning did provide students with the opportunity to achieve deeper learning of the course content, through the use of a learning environment and methodology that modelled the professional practice that they will enter on graduation. In addition, project-based learning provided students with the opportunity to develop a range of other skills necessary for professional practice and lifelong learning including teamwork, communication, negotiation of understandings and evaluation of

alternative views, reflection, organisational skills and the importance of learning for understanding. In the light of industry member and professional organisation comments in reviews of engineering education regarding the lack of these skills and abilities amongst current graduates of engineering programs, these outcomes are of significance to engineering education.

The study findings indicate that students undertaking project-based learning not only developed a good understanding of the skills and abilities necessary for professional practice in structural engineering, but also began to develop those skills. Given that these students were in the first course of three in structural engineering within the program, all of which involve project-based learning, it would be expected that these skills would continue to develop in subsequent courses. Hence these students should be able to function immediately in the professional workplace once they have completed their undergraduate studies, which should have significant benefits for graduate employers in particular and for the engineering profession as a whole.

The study involved the use of what have been termed assignment type projects (Kolmos, 1996). These projects are reasonably well defined by the lecturer in advance of the course, although the projects in the case study did not expect a correct answer, i.e., varied solutions were acceptable. The course in this case study also involved the use of traditional lectures and tutorials. The key difference was that the lectures and tutorials were integrated with the design projects, by providing the theoretical background necessary for students to undertake the projects in a just-in-time manner. The importance of this integration was clearly stated by students in the interviews and evaluations conducted in the case study.

The case study was not a problem-based course, where the problem guided the direction of study or the content of associated lectures, and nor was it within a project-organised curriculum, where the entire degree program is structured around project work. Both of these situations also may be very effective in engineering, and a project-organised curriculum such as at Aalborg University is probably the ideal example of project-based learning in engineering applied to the fullest extent. However, another factor of significance in this study was that it showed that project-based learning could be effective, even if only applied in an isolated course by an individual lecturer. In addition, the application did not involve radical amounts of additional work or preparation for the lecturer, rather a re-thinking and re-organisation of the content and timetabling previously used, and combining traditional methods with the application of practical experience. Hence, a further significant outcome of the study is that it demonstrates that project-based learning can begin to be applied within engineering education immediately, without major investments of funds or

time, or restructuring of programs. Whilst in the longer term a restructuring of all courses and programs towards the Aalborg model would seem to be the ideal to extend the use of project-based learning, there is no reason for individual lecturers not to begin to move in that direction within their own courses. In addition, for those lecturers who have already embarked on the path of project-based learning, the case study provides evidence to support the effectiveness of that move.

### **Limitations of the study**

The most obvious limitations of this case study were that it was limited to a single student cohort, undertaking a specific course *Building for People N*, taught a single time (Semester 1, 2001) at one institution – the University of South Australia, and that the researcher had the dual roles of teacher and researcher in the course. Recognising that these were limitations to the study is important, as is the implementation of measures to ensure the validity and reliability of the study outcomes, as discussed in Chapter 4. However, these limitations do not mean that the findings relating to the effectiveness of project-based learning should only be considered to apply to the particular situation of this case study. Possible extensions of the case study findings are discussed later in this chapter, but firstly the possible limitations of the findings will be examined more closely. These include:

- The halo effect
- Measures of student achievement
- How dependent were these findings on the particular background or skills of the researcher who instituted the case study and taught the course?
- Are the findings only applicable to Australian or South Australian students, or students with the particular backgrounds of those in the case study?
- Are the findings only applicable to structural engineering, or civil engineering, or engineering courses and to courses in later years of such programs?

These points will now be considered in turn.

#### **The halo effect**

This limitation relates to the fact that the researcher had dual roles in the course in the case study, one as a researcher and the other as the teacher/evaluator for the course. The halo effect relates to the objectivity of the researcher, i.e., that the researcher may believe that because he or she is undertaking the teaching/evaluating in the case study then that part of



the study is infallible. Hence, problems with the implementation or evaluation of the course may not be recognised in the research. The only real means of overcoming the halo effect limitation is to be aware that it exists in the first place and to demonstrate that suitable methods were put in place during the research to ensure reliability and validity of the research outcomes. The methods used in this research to ensure reliability and validity primarily involved triangulation between multiple data sources and a clear statement of the researcher's background and position. These measures have been extensively discussed in Chapter 4, and the background that the researcher brings to the study has been detailed in Chapter 1. Hence the halo effect has been recognised in this research and efforts have been made to overcome it. However, it should also be pointed out that the researcher's background and expectations of what should be able to be achieved through project-based learning in structural engineering do match closely with the desires and expectations of the engineering profession in practice, as detailed in the literature in Chapter 2 and demonstrated by the perceived curriculum evaluation discussed in Chapter 6.

#### Measures of student achievement

There are two primary limitations of the case study with regard to the measures of student achievement used within the course. Firstly, again related to the dual roles of the researcher, that the researcher both determined the evaluations and was responsible for marking them, and secondly, the nature of the assessment.

The limitation of having dual roles of researcher and evaluator is difficult to overcome. One suggestion in this regard would be to have external evaluation, either with respect to the marking of the assessments, or the setting of the assessments, or both. This was not possible in this study for several reasons. With regard to the projects, the setting of the assessment task was integral to the implementation of the intended curriculum. The projects were specifically framed so that they required students to undertake tasks and acquire skills as developed for the intended curriculum in the course, and the assessment of the projects was designed to measure the achievement of those skills. If a project developed by another person had been used, it would not have matched the intended curriculum as well as one developed by the researcher, and in any case, there is no available bank of projects to be accessed, so this was not a realistic option. Given that it was vital to the implementation of the intended curriculum that the projects be developed by the researcher, it could be argued that greater objectivity would be achieved if the completed projects were marked by another person, or checked again by another person after initial marking by the researcher. Whilst this would have been desirable, it was not practical in this study. Marking a single project generally takes at least 1.5 to 2 hours of time. For two projects, with an average of 13

submissions (eight student pairs and five individuals), the time required for marking is over 40 hours. With small faculty numbers in civil engineering at the University of South Australia, it was not reasonable to ask any other faculty member to undertake this marking on top of their own workload, and funds were not available to pay someone external to do it (the external person would also need to have some university teaching experience in structural engineering). In the absence of external marking of the projects, a detailed marking scheme was developed for the projects to endeavour to ensure consistency and objectivity of marking by the researcher. This has been discussed in Chapter 6.

With regard to the examination, the steel section of the assessment (worth 40% of the examination marks) was set by the second lecturer involved in the course (MPR), who was not involved in the case study research. The concrete section of the assessment (worth 60% of the examination) was set by the researcher. Both sections were marked by the researcher because the second lecturer was on study leave at the time of the examination. Each lecturer completed the other lecturer's section of the examination to check it for errors, missing or confusing information, before it was undertaken by the students. Marking of the steel section of the examination was undertaken by the researcher using the worked solutions and marking scheme developed by MPR, and marking of the concrete section also used a worked solution marking scheme. These measures endeavoured to ensure the objectivity of the examination questions and the evaluation of student solutions.

Another possible option was the use of externally set examinations or alternative assessments. In a similar way to the design projects, there is no bank of standard examination questions or complete tests available for undergraduate structural engineering in Australia, so this was not an option. A further option would have been to set a design task, similar to the projects, as the final assessment task, to assess whether the students could successfully undertake a design problem in another context than the projects. The difficulty with this option is that it requires more time to complete than the three hours allocated to the course for examination, and using more time would be unfair to students due to the fact that they have at least three other examinations for other courses to undertake in that period. Hence the compromise position was adopted of setting examination questions that were small components of the design tasks required in the projects. The examination paper and marking scheme used for it are included as Appendices B12 and B13.

### **Faculty member's skills and experience**

The researcher's background experience and beliefs were discussed in the introduction to the study in Chapter 1. It is certainly true that the researcher in this case was enthusiastic about

project-based learning and had extensive experience in structural engineering design in professional practice, hence the aspect of teaching through design projects was comfortable to her and did not require additional professional development. This may not be the case if a faculty member has only ever been engaged in academia and has not practised in industry, and may be considered to limit the possibility of the use of project-based learning by that staff member. However, this should not be seen as a limitation of the study or of the possibilities of project-based learning, but rather as a limitation of the faculty member that should be addressed through professional development. Recent reviews of engineering education have stressed the importance of having faculty members who have industrial experience, and preferably on-going professional registration. Significant numbers of engineering faculty do have such experience or continue to be involved in consulting work with industry. For those who do not, consideration should be given in staff development planning to allowing those faculty to undertake a semester of industrial placement as part of their professional development. This would enable them to develop design skills in their area of expertise, as well as to update their knowledge of current practices. Alternatively, industry practitioners can be used within such courses to assist with the design project aspect. However, the use of industry practitioners is unlikely to provide the best integration of the lecture, tutorial and project aspects of the course, which was seen as very important by the students in the case study. The involvement of industry practitioners also can be difficult to achieve due to the lack of suitable professionals with sufficient time to be involved in university courses in today's competitive economic climate. Recently retired people may be the best possibility. Hence, either the industry practitioners need to be involved with the complete course development and delivery, or the faculty member should use the participation of the industry practitioner as a professional development opportunity to develop sufficient skill to conduct the design projects on their own in future.

Another issue related to the researcher that may be perceived as a limitation of the study is teaching ability. Certainly, the researcher is considered to be a good teacher and has received peer recognition through awards to this effect. However, studies conducted amongst students about what they perceive to be the qualities of good teachers frequently cite such factors as enthusiasm, organisation and interest in students as being important. If a faculty member believes that they are not a good teacher (or student evaluations indicate this), they are possibly judging themselves on the basis of a traditional lecture-based course delivery model. An advantage of project-based learning is that it requires more active engagement of both students and faculty members and enables faculty to get to know students better in more informal classroom settings. Thus, the importance of delivering exciting and stimulating lectures is somewhat diminished, and whilst still desirable, that

ability will not limit the success of the course. If a faculty member is not interested in engaging with students or becoming more involved with teaching, then he or she probably would have difficulty in implementing project-based learning.

In summary, the particular background, experience and skills of the researcher in this study probably made it easier for her to implement project-based learning in the course in this case study, than may be the case for some other faculty members. However, it should not be seen as a limitation with regard to other faculty without such experience being able to implement project-based learning. Suitable professional development and support, combined with enthusiasm for improving teaching should be all that is needed for all faculty to be able to implement project-based learning in appropriate courses.

### Student cohort

A limitation of all case studies is that they examine an issue from the perspective of a particular group of people, in a specific situation, at a certain point of time. It is possible that the outcomes of the case study may have been different if a different cohort of students had been involved with the course. Part of the argument that can be made to counter this limitation relates to the discussion of internal validity, reliability and external validity that was included in Chapter 4. Another issue relates to whether the case study student cohort could be considered to be typical of most engineering students and hence whether the same course would be likely to be effective with another student group.

The characteristics of the student cohort in the study were described in some detail in Chapter 4. The cohort included students who had entered university immediately after completing high school and others who had come from other work experience or prior experience as civil engineering technicians. Students ranged in age from 20 to 35 and 24% were female. Two students were overseas residents, the rest were Australian residents but several spoke languages other than English at home. Academic abilities (as far as those assessed by earlier formal assessments go) ranged from outstanding to poor with a reasonable distribution in between. In other words, although there were only 21 students in the study cohort, they represented a very diverse range of backgrounds and abilities. The student bodies in many engineering programs are much less diverse, particularly at the more traditional universities considered to have greater prestige, where average academic abilities would normally be much higher, due to greater competition for entry places (as indicated by higher tertiary admission scores required for entry, e.g. South Australian Tertiary Admissions Centre, 2001). However, one should bear in mind the study of effective

engineers by Newport and Elms (1997), which showed that there was no correlation between academic achievement and effectiveness of engineers in the workplace.

The evidence gathered from the case study regarding the implementation of the skills and skill development amongst the students, their perceptions of the effectiveness of project-based learning as a learning method and their achievement of the learning outcomes was not limited to only a few, high achieving students in the cohort. Strong supporting evidence of these aspects was gathered from students across the cohort. It should be noted, however, that the students who were interviewed happened to be male and also happened to be non-school leaver students, but since the interview process was voluntary, this could not be changed by the researcher. These results would appear to indicate that if project-based learning is effective with the diverse group of students involved in this case study, it is likely to be effective with most engineering cohorts that are less diverse.

The findings of this study should certainly be limited in their application at this stage to students who have been through a basically western education system, i.e. Australian, English, Canadian, United States etc. and probably western European, where project-based learning is already used. Only one student in the case study cohort had come from an Asian education system, and it required considerable adjustment on her part to adapt to design projects, although she succeeded well in the end. All other students in the class had been educated in the Australian education system, or one that was also based on the English system (the Fijian student). The consideration of the difference that alternative cultural backgrounds and educational experiences of students may have on the effectiveness of project-based learning was beyond the scope of this study, and hence is a limitation of it, and provides scope for further research.

#### Applicability to other areas of engineering

The course in this case study was in the area of structural engineering. Projects are the basic mode of professional practice in all specialist areas of civil engineering, and examples from these areas were among those cited in the literature review of existing applications of problem- and project-based learning in Chapter 3. At the researcher's own university, projects have already been implemented in the areas of structural, geotechnical and water engineering. Hence, the methodology and findings of this case study should be able to be applied across all areas of civil engineering education. Of the other branches of engineering, mechanical engineering (and related fields such as mechatronic) is probably even better suited to project-based learning because the added phase of constructing the projects physically may be possible in many such areas. Examples of this were cited in Chapter 3.

The field of electronic/electrical engineering also would seem to be readily adaptable to project-based learning. Much of the literature relating to the critical issues of engineering education discussed in Chapter 2 was generic to all engineering and not specifically focussed on civil engineering, or structural engineering within that. Since project-based learning was shown in this case study to address many of these issues, it seems reasonable that its application should not be limited to only one or two specialist areas within engineering. Professional practice in all engineering fields involves engineers participating in projects, whether large or small, short or long term. Hence the use of project-based learning should be possible in all fields of engineering, and this case study could be used as a guide for its implementation and evaluation.

Another limitation to be examined is whether the effective use of project-based learning should be limited to courses in the later years of a program, after significant courses in basic science and mathematics have been undertaken. The Aalborg University model does not use project-based learning in the first year of the program, but the program at Central Queensland University does. At the University of South Australia, projects have been introduced into both first and second year classes, in engineering innovation and structural mechanics. However, the majority of early year classes are still taught in the traditional lecture and tutorial mode. The nature of projects in these classes would almost certainly be different from those that can be used in later year classes. Hence, although it is possible to introduce projects in the earlier years of an engineering program, the findings of this particular case study should probably be limited in application to projects in the later years of engineering programs. The findings of this study also could not be extended without further research to other fields of study than engineering. However, it is quite likely that the methodology and evaluation used within the study may have application in other professional fields, particularly related areas such as building.

## **Extending the Use of the Curriculum Model**

The curriculum model used in the study was developed for the evaluation of science-based curricula and was not specific to project-based curricula. The sequential and logical nature of the model probably appeals to the engineering sense of structure more than other models developed for education evaluation, which could be seen by engineering faculty to be more esoteric. When examining the usual type of planning and evaluation exercise that may be carried out by an engineering faculty member in relation to a course that he or she is teaching, it is likely that some important stages of the process are omitted. All courses will normally have some form of intended curriculum, developed formally at some stage in the past, but possibly becoming quite different as the course evolves. However, evaluation of

whether the intended curriculum is actually implemented is almost never done, and student perceptions related specifically to the curriculum are rarely determined. The achieved curriculum is usually only evaluated via formal assessment results. Hence, the use of the curriculum evaluation model and data collection methods as demonstrated in this case study could be of great value to engineering educators to improve the evaluation and effectiveness of their courses, whether they involved project-based learning or not.

Another important application that could be made of such a model is to use it as a means of complying with the accreditation body requirements for engineering program evaluation. For example the ABET accreditation guidelines for engineering programs in the United States have a strong focus on demonstrating outcomes. They also require “detailed published educational objectives...a process in which the objectives are determined and periodically evaluated...a curriculum and processes that ensure the achievement of these objectives and a system of ongoing evaluation that demonstrates achievement of these objectives...” (ABET, 1999). In other words the guidelines require an intended curriculum (educational objectives), implemented curriculum (processes that ensure achievement of the objectives) and achieved curriculum (demonstrate achievement of the objectives), and the perceived curriculum would be an important factor in the evaluation of the objectives as well.

Thus the use of the curriculum evaluation model in this case study, and the means and types of data collected within the case study, could be extended more widely in engineering education. They could be used by individual faculty members within single courses, by groups of faculty to develop and evaluate course streams (e.g., the structural engineering set of courses), by individual departments/schools for engineering programs and by entire divisions for accreditation. It would not be necessary to collect all of the types of data used in this study every time any course was taught, but various data could be collected over several semesters to build up a picture of the course or program effectiveness. For accreditation applications, it would also be necessary to collect data from graduates of a course or program after they had entered the workforce, as well as from employers of the university’s graduates.

## **Expanding the Use of Project-based Learning in Engineering**

The case study has demonstrated that project-based learning is an effective method of teaching and learning for structural engineering, and the foregoing discussion has indicated that the method could be extended to other areas of civil engineering and engineering in

general. One requirement for this extension would be faculty having the necessary expertise to use design projects in their teaching, as discussed under the limitations of the study.

Several other issues also may need to be addressed to extend project-based learning more widely within engineering. A primary requirement for extending the use of project-based learning in engineering would be coordination and cooperation between faculty members, which will possibly need a mind shift from the current individualist thinking and programming that is prevalent in some university engineering departments. The workload implications would need to be recognised, for both faculty members and students, in changing to a new methodology and then in the application of it. However, this case study did indicate that students believed the workload was reasonable, and for faculty the workload is different, not necessarily more. The development of intended curricula for a full program to incorporate project-based learning would need more than just industry guidelines to formulate it, although they would certainly be important in determining the technical skill requirements. Accreditation guidelines would form an important part of generic skill guidelines and the knowledge and experience of the faculty would be crucial in bringing these pieces together. Suitable workspaces to enable group discussions in informal settings would assist in the implementation of project-based learning. Lastly, an examination of accounts of the difficulties of implementation and how these were overcome, written by institutions that have already instituted problem-based or project-based learning programs in engineering, would be an important step to take before implementing it at another institution.

However, as pointed out earlier in the discussion, this case study demonstrated that project-based learning was effective even when only implemented within a single course by a single faculty member. Hence none of these issues should be used as a reason for not starting to use project-based learning in individual courses and gradually building it into more parts of an engineering program as faculty experience, expertise and confidence in its use develops.

## **Summary**

This chapter has summarised the responses to the four questions posed at the start of the study that were obtained from the case study research conducted. In addition, the significance and limitations of the study findings have been examined. Finally, possible extensions to other areas of engineering of both the curriculum evaluation model used in the case study and the use of project-based learning in general have been discussed.

The overall conclusion of this case study was that project-based learning was shown to be a very effective method of learning in the field of structural engineering, which modelled



professional practice and instituted deeper learning than traditional lecture-centric modes of instruction. Students gained both technical skills in structural engineering and generic skills relevant not only to engineering practice, but also to their ability to undertake lifelong learning. The use of project-based learning should be encouraged not only within structural engineering but also within all areas of all disciplines of the engineering profession.

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# Appendices

## **Appendix A**

**Appendix A1: ABET: Engineering Criteria 2000**

**Appendix A2: Institution of Engineers, Australia – Structural College: Guidance notes for membership reviewers**

## **Appendix A1: ABET Engineering Criteria 2000**

**Note: For copyright reasons the contents of Appendix A1 has not been reproduced.**

**(Co-ordinator, ADT Project (Retrospective), Curtin University of Technology, 1.5.03)**

**Appendix A2: Institution of Engineers, Australia – Structural College:  
Guidance notes for membership reviewers, Draft 1, November, 2000**

**Note: For copyright reasons the contents of Appendix A2 has not been reproduced.**

**(Co-ordinator, ADT Project (Retrospective), Curtin University of Technology, 1.5.03)**

## **Appendix B**

Appendix B1: Building for People N – Course Handout 2001

Appendix B2: Building for People N – Design project 1 handout

Appendix B3: Building for People N – Design project 2 handout

Appendix B4: Researcher's concept map of structural engineering

Appendix B5: Building for People N – Curriculum Plan

Appendix B6: Building for People N – Lesson Plan

Appendix B7: Information sheet and call for volunteers

Appendix B8: Building for People N – Course evaluation questionnaire

Appendix B9: Building for People N – Perceived curriculum evaluation

Appendix B10: Project 1 – Allocation of marks to generic and technical skills

Appendix B11: Project 2 – Allocation of marks to generic and technical skills

Appendix B12: Building for People N – Examination paper

Appendix B13: Exam questions – Allocation of marks to generic and technical skills



UNIVERSITY OF SOUTH AUSTRALIA  
SCHOOL OF GEOSCIENCE, MINERALS & CIVIL ENGINEERING

## **BUILDING FOR PEOPLE N - 2001**

### **TIMETABLE**

Please refer to attached timetable – **read carefully!**

### **LECTURERS**

Julie Mills, H3-14                      Course Coordinator  
Mahes Rajakaruna, H3-20

### **LEARNING OBJECTIVES OF THE COURSE**

Within the context of the design of structures in both steel and reinforced concrete, the learning objectives for this course are:

1. To introduce the basic structural principles of stability, strength and serviceability and their importance in design.
2. To introduce the concepts of limit state design.
3. To enable students to understand and determine the design loads on simple structures arising from the design actions of gravity, occupation and use of the structure, and wind.
4. To apply the fundamental knowledge of materials and mechanics gained in earlier courses to the practice of structural design.
5. To gain technical competence in the following specific areas of structural analysis and design:
  - Analysis of simple structures to determine the axial loads, shear forces and bending moments and deflections on structural elements resulting from the application of the design loads.
  - Design of the following individual structural elements in steel and reinforced concrete for strength, stability and serviceability
    - Tension members
    - Compression members
    - Beams
    - Members in combined bending and tension/compression
    - Reinforced concrete slabs and footings.



- Consideration of the stability of a complete structure under wind loads.
6. To become familiar with Australian Standards AS 1170.1, 1170.2, 3600 and 4100.
  7. To develop the ability to communicate design processes and outcomes in a manner acceptable to the engineering profession, through calculations and drawings.

## **COURSE STRUCTURE / TEACHING AND LEARNING PHILOSOPHY**

The learning objectives of the course will be achieved through a variety of teaching and learning methods, as well as self-study by the student. These will include:

### *Lectures/tutorials*

- To introduce and expand on concepts, provide worked examples of their application, and give students the opportunity to develop skills through solving short problems as individuals or in small groups.
- Students will be expected to have read assigned sections of the texts as advised before the class. Lectures and supplied lecture notes will complement, but not duplicate the recommended text books.

### *Laboratory Practicals*

- To provide visual demonstrations and hands-on experience of the modes of structural failure of reinforced concrete beams and columns, and to relate these to the design methods used in practice.

### *Projects*

- To provide an opportunity to integrate and further develop the concepts introduced in lectures by carrying out designs of complete structures using industry examples.
- To allow collaboration among students to develop and discuss their conceptual understanding by facilitating small group interactions, and open discussions in project sessions.
- To familiarise students with the Australian standards relevant to the projects.
- To develop students' ability to communicate their design through calculations and drawings.

### *Site Visit(s)* (location and date to be advised)

- To provide students with the opportunity to see the conceptual design presented through drawings and calculations becoming a physical reality, and introduce them to relevant construction methods.

## **TEXTS**

It is compulsory for students to have the following texts available at all times during the course (i.e. bring them to lectures). References are intended to supplement the

text-books and provide additional information. All texts will continue to be used in subsequent courses in the program.

### **Compulsory Textbooks**

Design of Steel Structures to AS4100 – lecture notes, Julie Mills, Mahes Rajakaruna (available from the School Secretary, \$10.00) **This is required by Week 2**

Trahair, N.S. & Bradford, M.A., 1998. *The Behaviour and Design of Steel Structures to AS 4100*, 3<sup>rd</sup> Edition – Australian, E & FN Spon.

HB2.2 *Australian Standards for Civil Engineering Students, Part 2: Structural Engineering*, 1998 edition, (available from the School Secretary at \$45.00 until sold out, after that students will need to obtain this direct from Standards Australia) **This is required by Week 2**

Warner, R.F., Rangan, B.V., Hall, A.S. and Faulkes, K.A., 1998. *Concrete Structures*, Longman. (this will be required from mid-semester break)

### **References (on reserve in the library)**

Gorenc, B., Tinyou, R. and Syam, A., 1996. *Steel Designers' Handbook*, 6<sup>th</sup> edition, UNSW Press. (this will be particularly useful for the project)

Hogan, T.J. & Thomas, I.R. (4<sup>th</sup> ed.) 1994. *Design of structural connections*. Sydney: Australian Institute of Steel Construction

Australian Institute of Steel Construction (2<sup>nd</sup> ed.), 1994 *Design Capacity Tables for Structural Steel, Volume 1: Open Sections*, AISC

Cement and Concrete Association of Australia (3<sup>rd</sup> ed), 1995. *Concrete Design Handbook*.

### **ASSESSMENT**

Design Projects	40%
Practicals	10%
June Examination (1 x 3 hour paper concrete)	50% (40 marks steel, 60 marks concrete)

*Tutorials are essential to develop the understanding of lectures and student reading, but tutorials will not be assessed. However diligence in the tutorials may be rewarded in the case of any student who is struggling to pass the course.*

Satisfactory completion and reporting of laboratory work is required for a pass in this course.

Practical reports shall comprise a group report of all results and computations, with an interpretation of the test procedure and comments on the reliability of the observations. Reports should include all group members' names and be submitted within one week of the practical. **Attendance and participation** records will be kept for all practicals. If a majority of members of a group identify a non-participating member, that member will not be given credit for the report.

Unsatisfactory practical reports must be redeemed.

## **LABORATORY CLASSES**

Practical groups will be resolved in the first couple of weeks of classes. If you believe that you have grounds for exemption from the practical component of the course, please see Julie Mills during the first couple of weeks.

**BUILDING FOR PEOPLE N - FIRST SEMESTER - 2001**

WEEK	MONDAY 1 TO 3 NI-12	TUESDAY 9 TO 12 P1-11	TUESDAY 12 TO 2 LABS/ NI-12
1 Feb 26 to Mar 2	Limit States Lecture/Tutorial - JEM	Steel Lecture/ Tutorial - MPR	Wind Loads / DESIGN PROJECT 1
2 Mar 5 to 9	DESIGN PROJECT 1	Steel Lecture/ Tutorial - MPR	
3 Mar 12 to 16	DESIGN PROJECT 1	Steel Lecture/ Tutorial - MPR	
4 Mar 19 to 23	DESIGN PROJECT 1	Steel Lecture/ Tutorial - MPR	
5 Mar 26 to 30	DESIGN PROJECT 1	Steel Lecture/ Tutorial - MPR	
6 Apr 2 to 6	DESIGN PROJECT 1	Steel Lecture/ Tutorial - MPR	
<b>SEMESTER BREAK</b>			
7 Apr 23 to Apr 27	Concrete Lecture/Tutorial JEM	Concrete Lecture/Tutorial JEM	Concrete Lecture/Tutorial DESIGN PROJECT 2 JEM
8 Apr 30 to May 4	No lecture (JEM away) <i>Fri 27 Apr, session to catch up???</i>	No lecture (JEM away)	
9 May 7 to 11	Concrete Lecture/Tutorial JEM	Concrete Lecture/Tutorial JEM	Beam Prac MPR Group 1 Design Project JEM Group 2
10 May 14 to 18	Concrete Lecture/Tutorial JEM	Concrete Lecture/Tutorial JEM DESIGN PROJECT 2	Beam Prac MPR Group 2 Design Project JEM Group 1
11 May 21 to 25	Public Holiday	Concrete Lecture/Tutorial JEM	Column Prac MPR Group 1 Design Project JEM Group 2
12 May 28 to June 1	DESIGN PROJECT 2	Concrete Lecture/Tutorial JEM	Column Prac MPR Group 2 Design Project JEM Group 1
13 June 4 to 8	DESIGN PROJECT 2	Concrete Lecture/Tutorial JEM	

## Appendix B2

### CIVIL ENGINEERING DISCIPLINE - BUILDING FOR PEOPLE N

#### DESIGN PROJECT 1 - INDUSTRIAL BUILDING

##### 1. PROJECT EXTENT

Design and draw the main structural elements as listed below for the single storey industrial building shown on the attached drawing. This project is worth **20 marks** of the final course assessment.

As you have started the structural engineering courses at this stage, you are not being asked to carry out a complete design for the building. Only a limited number of aspects will be included, other aspects will be covered in later projects and courses. In particular, the following areas that would have to be considered in a full design, will **not** be covered in this project:

- Earthquake design
- Fire resistance
- Roof sheeting and purlin design
- Wall cladding and support design
- Ground floor slab and footing design

Many of these will be considered in projects in Structural Engineering 1 or Civil Engineering Advanced Topics.

##### 2. BUILDING CONSTRUCTION

**2.1 Exterior Walls:** Metal sheeting (say 0.5 mm thick) on steel girts

**2.2 Roof:** Metal sheeting (say 0.5 mm thick) on steel purlins, no ceiling or air conditioning.

**2.3 Floors:** Reinforced Concrete ground floor slab.

##### 3. CODES (all in HB2.2)

Loads	AS 1170.1 - Dead and Live Loads and Load Combinations AS 1170.2 - Wind Loads
Design	AS 4100 - 1990, Steel Structures AS 3600 - 1994, Concrete Structures

##### 4. ASSESSMENT, EXTENT OF WORK

Due to the short duration available for the project it is preferable that you **work in pairs** to enable a more thorough effort. If you elect (or are directed) to work individually, mark and extent of work adjustments will be made (see below). Please note the initials of the student responsible for particular calculations on each page or include a summary of how you distributed the work between you in your final report.

The required elements to be designed, allocated marks and estimated design time required are detailed in the table below. The determination of these element layouts would normally be part of your design process. Items marked \* may be deleted by people doing the project individually. Their marks will be factored accordingly (ie. by 100/80). Pairs may also choose to omit these items, but their marks will not be scaled up (ie they choose to do a project with lesser extent and less marks).

Item	Allocated %	Estimated Completion Date
Wind load determination, consisting of: <ul style="list-style-type: none"> <li>• Design wind speed</li> <li>• External pressures</li> <li>• Internal pressures</li> </ul>	14 3 7 4	12 March 01
Overall building stability under wind i.e. roof and wall bracing, consisting of: <ul style="list-style-type: none"> <li>• layout and member load determination</li> <li>• tension members design</li> <li>• compression members design</li> </ul>	10 4 3 3	19 March 01
Rafter, R1 design, consisting of: <ul style="list-style-type: none"> <li>• determine design loads for strength &amp; serviceability</li> <li>• serviceability design</li> <li>• strength design - section moment capacity</li> <li>• strength and stability design - member moment capacity (including effective lengths) for worst up and down load combinations</li> </ul>	15 5 3 2 5	26 March 01
*Ridge Beam, RB1 design, consisting of: <ul style="list-style-type: none"> <li>• determine design loads for strength &amp; serviceability</li> <li>• serviceability design</li> <li>• strength design - section moment capacity</li> <li>• strength and stability design - member moment capacity (including effective lengths) for worst up and down load combinations</li> </ul>	8 2 2 1 3	26 March 01
Column design C1, consisting of: <ul style="list-style-type: none"> <li>• determine axial loads and bending moments</li> <li>• strength design – tension (uplift)</li> <li>• strength and stability design - compression</li> <li>• strength and stability design - bending</li> <li>• strength and stability design - combined actions</li> </ul>	15 3 2 3 3 4	2 April 01
*Column design C2, consisting of: <ul style="list-style-type: none"> <li>• determine axial loads and bending moments</li> <li>• strength design – tension (uplift)</li> <li>• strength and stability design - compression</li> <li>• strength and stability design - bending</li> <li>• strength and stability design - combined actions</li> </ul>	12 2 2 2 2 4	2 April 01
Rafter R1- Column C1 connection for worst case <ul style="list-style-type: none"> <li>• bolt design</li> <li>• weld design</li> </ul>	6 4 2	10 April 01
Presentation and Drawings <ul style="list-style-type: none"> <li>• Plan view with roof and wall bracing locations and all elements labelled</li> <li>• Member schedule giving details of each labelled member type</li> <li>• Rafter-column connection detail</li> <li>• Journal and overall presentation of calculations</li> </ul>	20 5 3 4 8	10 April 01
<b>Total</b>	<b>100% x 0.20 =20 marks</b>	

## 5. ADDITIONAL DESIGN INFORMATION

### *Wind Loads*

The building is to be located in the industrial estate area of Regency Park, on the eastern side of South Road. The roller doors in the side and end walls are 4m wide x 3.6m high. There is no roof vent.

### *Roof Beams*

The roof sheeting will be fixed to steel purlins running along the length of the building. They will be attached to the top flange of the roof beams (rafters, R1) and hence provide lateral restraint to the top flange of these beams. Assume that all purlins will be spaced at 1200 mm centres. Rafters R1 will be connected into each side of the Ridge Beam, RB1, i.e. the top flanges of all beams at the ridge point will be at the same level.

### *Columns*

The wall sheeting will be fixed to steel girts running along the length of the building. The girts will be attached to the outside flange of the columns. Assume that girts will be spaced at maximum spacing of 1500 mm centres. Columns C1 and C3 will be constructed from Universal Beam sections. The internal column C2 will be a square hollow section (SHS), data for these columns is attached in this brief.

## 6. DRAWINGS

The drawings should summarise your design, but remember they are design drawings not shop drawings, hence only member sizes and critical dimensions are required.

## 7. REFERENCES (all on reserve)

Gorenc, B., Tinyou, R. and Syam, A., *Steel Designers' Handbook*, 6<sup>th</sup> edition, UNSW Press, 1996

Hogan, T.J. & Thomas, I.R. (4<sup>th</sup> ed.) 1994. *Design of structural connections*. Sydney: Australian Institute of Steel Construction

M.A. Bradford, R.Q. Bridge and N.S. Trahair (2<sup>nd</sup> Ed), *Worked examples for steel structures: worked design examples for steel structures according to strength limit states of AS4100-1990 AISC*

## 8. PROJECT PRESENTATION

The project shall be presented fixed inside a folder with your names on the front cover and shall include:

- Disclaimer that project is your own work (i.e. you and your partner)
- Index
- Calculations
- Drawings

**NOTE:** Drawings to be on A3 or A4 sheets with photocopies of the original drawings placed at the back of the folder. CAD drawings preferred but pencil line drawings acceptable.

**Please do not use a "Display" folder with individual sheets within the plastic covers, they are a pain to mark.**

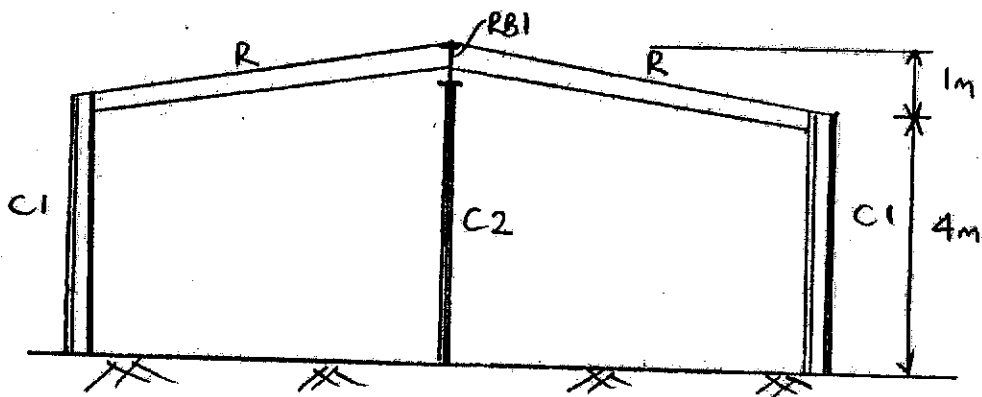
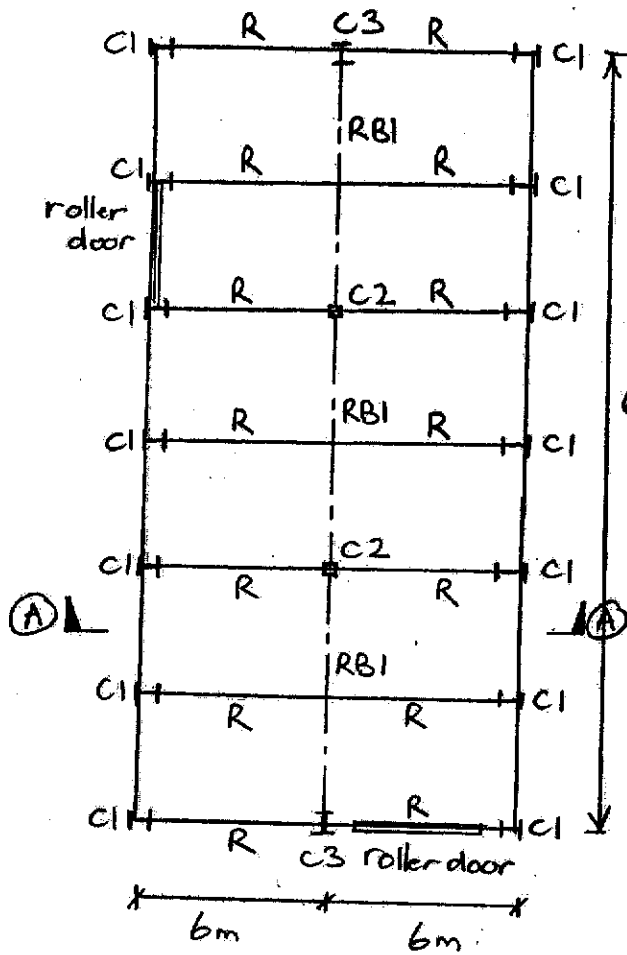
## 9. COMPLETION DATE

The project shall be handed in completed or otherwise, by **9.00 a.m. on Wednesday, 10 April 2001.**

Projects will not be accepted after 9.00 a.m. on **Wednesday, 10 April 2001** unless some acceptable extenuating reason is produced, e.g. sickness (supported by a medical certificate).

**NOTE:** Failure to submit the project by the due date will result in preclusion from the examination.

**JULIE MILLS**





## Appendix B3

# CIVIL ENGINEERING DISCIPLINE - BUILDING FOR PEOPLE N

## DESIGN PROJECT 2 – TWO-STOREY HOUSE

### 1. PROJECT EXTENT

Design and draw the specified structural elements as listed below for the two storey house shown on the attached drawings. It is a residence that was constructed in Highbury. This project is worth 20 marks of the final subject assessment.

As you have only done part of the structural engineering subjects to this stage, you are not being asked to carry out a complete design for the building. Only a limited number of aspects will be included, other aspects will be covered in later projects and subjects. In particular, the following areas that would have to be considered in a full design, will **not** be covered in this project:

- Wind Load frame design
- Earthquake design
- Fire resistance
- Roof cladding and support design
- Masonry wall design
- Ground floor slab design and footings

Many of these will be considered in projects in Structural Engineering 1 or Civil Engineering Advanced Topics.

### 2. BUILDING CONSTRUCTION

**2.1 Exterior Walls:** Masonry veneer construction external wall, in-fill panels (i.e. non-load-bearing) between reinforced concrete frame on the upper floor. Internal walls on the upper floor are timber framed or masonry (refer drawings). Solid masonry walls to ground floor, also non-load-bearing, however we will assume that the walls surrounding the garage are **load-bearing** for this project.

**2.2 Roof:** Metal sheeting on timber roof trusses, with plasterboard ceiling.

**2.3 Floors:** Reinforced Concrete suspended first floor slab, cast integrally with reinforced concrete beams.

### 3. CODES (all in HB2.2)

Loads	AS 1170.1 - Dead and Live Loads and Load Combinations AS 1170.2 – Wind Loads
Design	AS 3600 - 1994, Concrete Structures

### 4. ASSESSMENT, EXTENT OF WORK

Due to the short duration available for the project it is preferable that you **work in pairs** to enable a more thorough effort. If you elect (or are directed) to work individually, mark and extent of work adjustments will be made (see below). Please note the initials of the student responsible for particular calculations on each page or include a summary of how you distributed the work between you in your final report.

The required elements to be designed, allocated marks and estimated design time required are detailed in the table below. The determination of these element layouts would normally be part of your design process.

Items marked \* may be deleted by people doing the project individually. Their marks will be factored accordingly (ie. by 100/80). Pairs may also choose to omit these items, but their marks will **not** be scaled up (ie they choose to do a project with lesser extent and less marks).

Item	Allocated %	Estimated Completion Date
<b>Slab Panel A (one-way):</b> <ul style="list-style-type: none"> <li>Determine thickness for serviceability using Warner's method</li> <li>Determine design loads, bending moments &amp; shears in accordance with Sec 7.2</li> <li>Design reinforcement for bending, check minimum.</li> <li>Design reinforcement for crack control etc.</li> </ul>	<b>11</b> 2 4 3 2	14 May 01
<b>Slab Panel B (two-way):</b> <ul style="list-style-type: none"> <li>Using same thickness as Panel A, determine design loads, bending moments to Sec 7.3</li> <li>Design reinforcement for bending, both directions</li> <li>Check reinforcement for crack control etc.</li> </ul>	<b>9</b> 3 4 2	21 May 01
<b>Beam CB1:</b> <ul style="list-style-type: none"> <li>determine design loads for strength</li> <li>determine design BM's and shears to Sec 7.2</li> <li>Design reinforcement for +ve and -ve bending</li> <li>Design reinforcement for shear</li> </ul>	<b>20</b> 5 4 6 5	28 May 01
<b>*Beam CB2:</b> <ul style="list-style-type: none"> <li>determine design loads for strength</li> <li>determine design BM's and shears to Sec 7.2</li> <li>Design reinforcement for +ve and -ve bending</li> <li>Design reinforcement for shear</li> </ul>	<b>12</b> 4 2 4 2	28 May 01
<b>Column C1 (between ground and first floor):</b> <ul style="list-style-type: none"> <li>determine axial compressive loads and min BM's</li> <li>determine whether short or slender</li> <li>develop the column interaction diagram, assuming minimum steel, and check adequacy</li> <li>check your design using column charts supplied</li> </ul>	<b>15</b> 4 2 7 2	4 June 01
<b>*Column C2 (between ground and first floor):</b> <ul style="list-style-type: none"> <li>determine axial compressive loads and min BM's</li> <li>determine whether short or slender</li> <li>design using column charts</li> </ul>	<b>8</b> 4 2 2	4 June 01
<b>Drawings:</b> <ul style="list-style-type: none"> <li>Plan view of Slab Panel B reinforcement</li> <li>Beam CB1 elevation and critical sections</li> <li>Elevation of slab panel A, CB1, Column C1 and indicative footing, to underside of roof, and section through Col C1</li> <li>Journal and overall presentation of calculations</li> </ul>	<b>25</b> 3 7 7 8	12 June 01
<b>Total</b>	<b>100% x 0.20 =20 marks</b>	<b>Or 80% x 20/80 =20 marks (individuals)</b>

## 5. ADDITIONAL DESIGN INFORMATION (Please read carefully before you ask questions!!)

Due to the short time-frame and limited extent of this project, several simplifying assumptions will be made as follows:

- Balconies will be ignored
- All upper floor internal walls over the slab area to be designed will be considered to be timber-frame.
- The simplified method may be used to determine the bending moments and shears for Beam CB1, even though the span ratio is slightly greater than 1.2. (For Beam CB2, you will need to use the 3 moment equation)

### *Wind Loads*

Whilst for the full design, the wind loads would need to be determined for both roof design and the reinforced concrete frame design, this will not form part of the project. Hence you do not need to determine wind loads on this structure.

### *Roof Beams*

Design of the steel perimeter roof beams, timber roof trusses etc will not be part of this project. Assume a load of **0.4 kPa** for the complete roof, beams, ceiling and airconditioning assembly. Since the roof is a truss assembly, all roof load will be transferred to the ground through the external concrete columns.

### *Columns*

Assume the columns are braced and concrete compressive strength at 28 days is **32 Mpa**. In this particular house they are braced due to the slope of the block which meant that the eastern end of the lower floor consists of substantial retaining walls. These walls act as shear walls to brace the lower floor columns. The upper floor columns in this building would have been designed as cantilevers above the first floor level. However, you are only required to design the ground floor columns, so just assume the braced condition.

### *Walls*

The external walls on the upper floor are masonry veneer, i.e. they have a single leaf of brickwork on the outside and the internal leaf is timber framed. These panels will only support their own self-weight (this would require detailing of the wall support at the top and bottom). The major structural loads, including the total loads from these walls, will be carried by the reinforced concrete frame. Assume a load of **2.4 kPa** for these walls, multiply this by the height of the wall to give the line load (kN/m) imposed on the beams by these walls. For the internal timber frame walls, assume a load of **0.4 kPa x wall height** (kN/m) where a wall lies directly above a beam (as in the Living/Family Room wall in this case). Elsewhere, allow a pressure on the supporting slab of **0.2 kPa** for the other internal walls (i.e. add this as a dead load to the slab self-weight).

### *Beams and slabs*

Reinforced concrete beams and slabs will be cast integrally, with slabs and beams continuous over more than one span. Assume **32 Mpa** strength for all. In practice, the entire first floor of slab and beams would be poured at one time. As we will not be covering beam deflections in lectures until late in the semester, they will not be checked in the project (they are unlikely to be a problem in a residential structure, due to the light floor loads). Slab deflections will be considered by using Warner's preliminary design method to determine the slab thickness.

### *Footings*

Footings will be reinforced concrete pads with 28 day strength of **20 MPa**. This particular house was built on rock, so only nominal pad footings were used. They will not be designed in this project.

## **6. DRAWINGS**

The drawings should summarise your design, but remember they are design drawings not reinforcement scheduling drawings, hence only critical member dimensions, bar sizes, numbers, ligature spacing etc are required. However, you should follow the conventions for reinforced concrete detailing (see reference) and show critical lap locations etc.

## **7. REFERENCES**

Warner, R.F., Rangan, B.V., Hall, A.S. and Faulkes, K.A. *Concrete Structures*, Longman, 1998

Brian J. Ferguson, 1989, *Reinforcement detailing handbook for reinforced and prestressed concrete: based upon the Australian Concrete Structures Standard AS 3600-1988*

## **8. PROJECT PRESENTATION**

The project shall be presented fixed inside a folder with your names on the front cover and shall include:

- Disclaimer that project is your own work (i.e. you and your partner)
- Index
- Calculations
- Drawings

**NOTE:** Drawings to be on A3 or A4 sheets with photocopies of the original drawings placed at the back of the folder. CAD drawings preferred but pencil line drawings acceptable.

**Please do not use a "Display" folder with individual sheets within the plastic covers.**

## **9. COMPLETION DATE**

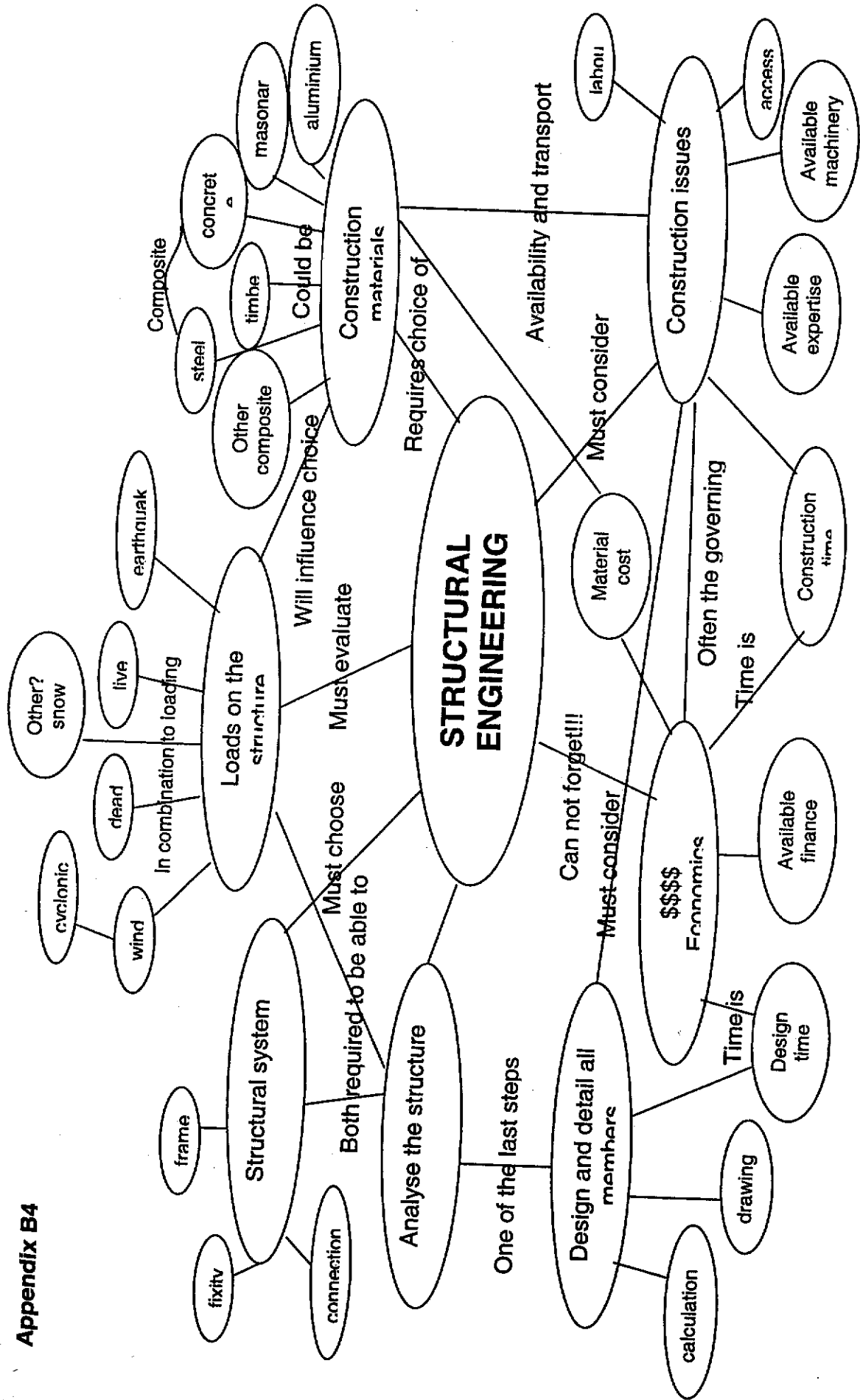
The project shall be handed in completed or otherwise, by **10.00 a.m. on Tuesday, 12 June 2001**.

Projects will not be accepted after 10.00 a.m. on **Tuesday, 12 June 2001** unless some acceptable extenuating reason is produced, e.g. sickness (supported by a medical certificate).

**NOTE:** Failure to submit the project by the due date will result in preclusion from the examination.

**JULIE MILLS**

Appendix B4



## Appendix B5 - Curriculum Plan incorporating Intended curriculum, Implementation of this and Assessment in Building for People N, 2001

Skill	Intention – what am I trying to achieve?	Implementation – how do I propose to do this	Assessment – how will I tell if this has been achieved?
<p><i>Generic skills</i></p> <p>1. Apply basic fundamentals</p>	<p>This is generic throughout the course. Students have previously studied mathematics, physics, chemistry, engineering materials, structural mechanics. This course is the first opportunity to apply that fundamental knowledge to structural design.</p>	<p>Throughout the course – lectures, tutorials, practicals, projects</p>	<p>Through all components of assessment – exam, projects and prac reports. Difficult to separate proportions of skill learnt through each component. Overall assessment is probably the only valid measure.</p>
<p>2. Communicate effectively</p>	<p>Verbal communication: only informal in this course, no oral presentations etc.</p> <p>Written/graphic communication: students to become familiar with acceptable presentation of calculations and drawings.</p>	<p>Written/graphic – students required to present their calculations and drawings of design project to a professional standard. Some instruction/references in project handouts, verbal references in class, feedback in assessment.</p> <p>Practical reports will also be assessed for communication, but this is not done by me.</p> <p>Throughout the course – lectures, tutorials, practicals, projects</p>	<p>Marks assigned to drawings in project, as well as overall presentation (?)</p>
<p>3. In-depth technical competence</p>	<p>Also generic throughout the course</p>	<p>Throughout the course – lectures, tutorials, practicals, projects</p>	<p>Through all components of assessment – exam, projects and prac reports. Difficult to separate proportions of skill learnt through each component. Overall assessment is probably the only valid measure.</p>
<p>4. Problem identification, formulation and solution</p>	<p>Problems in this course are already identified and largely formulated. Examples of problem solution are presented. Limited in this course to solution of a fairly well defined problem, although there is no “right answer”, in the design projects.</p>	<p>Problem solution of completely defined problems is implemented in the exam.</p> <p>Problem solution of defined problem but with various acceptable solutions is implemented in the design projects.</p>	<p>Exam overall marks assess the first case (as far as exams can, but that is another debate).</p> <p>Project overall marks assess the second case.</p>

Skill	Intention – what am I trying to achieve?	Implementation – how do I propose to do this	Assessment – how will I tell if this has been achieved?
<p><i>Technical skills</i></p> <p>11. Stability, strength, serviceability</p>	<p>An understanding of the importance of each component and that you can't just satisfy one and not others. How to satisfy the requirements of each component.</p>	<p>Lectures/tutorials – techniques for satisfying each component presented, as well as examples demonstrating that all are considered in design</p> <p>Projects – requirement of design for each component within the project, and marking scheme demonstrates that each must be considered for design of the structure.</p>	<p>Exams – marks allocated for specific sections of questions relating to each component.</p> <p>Projects – marks allocated specifically to each component within the marking scheme.</p>
12. Loads	<p>An understanding of how to determine the design loads on a structure. An understanding of Limit State Design.</p>	<p>Lecture presented on Limit State Design and Wind loads.</p> <p>Project – requirement for calculation of loads in both projects</p>	<p>Projects – marks allocated specifically for load determination. (not assessed in exam)</p>
13. Functional and economic	<p>An understanding that other factors influence design than just the numbers, particularly construction issues. This is developed further in later courses.</p>	<p>This will be discussed informally in lectures and project sessions.</p> <p>Site visit used to illustrate these issues</p>	<p>Not specifically assessed</p>
16. "Visualise" failure mechanisms	<p>Introduction only in this course, developed much more in later courses.</p>	<p>Pictures presented of failure mechanisms for steel in lectures.</p> <p>Practical sessions demonstrate failure mechanisms for concrete.</p> <p>Overall structure failure mechanisms not part of this course except wind stability</p>	<p>Not specifically assessed</p>



Skill	Intention – what am I trying to achieve?	Implementation – how do I propose to do this	Assessment – how will I tell if this has been achieved?
<i>Technical skills cont.</i>			
17. Knowledge of analysis, design, construction.	Analysis – only simple in this course, developed much more in later courses Design – the basis of this course Construction – introduction only	Analysis – basic analysis required in design projects to determine BM, Shear, axial loads etc. Design – throughout course Construction – site visit and informally in lectures	Marks allocated to analysis and design components in project marking scheme. Exam will also assess design.
18. Australian standards	Initial understanding of relevant standards in loading (1170.1&2), steel structures (4100) and concrete structures (3600).	Lesson plan and lecture notes provide specific references to standards clauses. Design project is all required to be carried out to Australian Standards.	Construction not assessed in this course.  Loading standards: marks allocated to load determination in project.  Steel and concrete standards: marks allocated to design components of project will be relevant to this.
19. Computer programs and design aids	Computer programs not used in this course – more in later courses Students to be aware that design manuals in steel and concrete exist and are widely used for standard designs.	Availability of design manuals in steel and concrete is discussed, minor use of concrete manual for column design.  Manuals are in reference list in handout and on reserve in library.	Marks allocated to column design by manual in Project 2
21. Engineering drawings	Give students their first opportunity to present their design information on drawings.	Drawings required for design project and sketches encouraged in calculations.	Marks allocated to drawings in design projects.

## Appendix B6 - BUILDING FOR PEOPLE N - Lesson Plan - JEM

Week	Project Session	Lecture/Tutorial
<p>1 (Feb 26, 27) Mon - Proj. 2 hrs Tues - Lect 3 hrs Tues - Proj 2 hrs</p>	<p><i>Monday</i> What is a structure? Types of loads - design actions Structural design process Limit states</p> <ul style="list-style-type: none"> <li>• Class group exercise - carport design</li> </ul> <p>Hand out Project 1 - brief discussion, read for questions on Tuesday</p> <p><i>Tuesday</i> Project questions, discussion PhD study explanation and info sheet handout Wind loads</p> <ul style="list-style-type: none"> <li>• General introduction</li> <li>• Calculation of <math>V_z</math>, <math>P_z</math></li> <li>• Use project as the tutorial for wind load calcs.</li> </ul>	<p>Steel - MPR Tension member design</p>
<p>2 (Mar 5, 6)</p>	<p>Project - continue with wind load calcs as a "tutorial"</p> <ul style="list-style-type: none"> <li>• External pressures</li> <li>• Internal pressures</li> </ul> <p>Roof and wall bracing introduction</p> <p><i>Project schedule - By 12 March, complete wind load calcs., determine bracing layout</i></p>	<p>MPR Compression members</p>
<p>3 (Mar 12, 13)</p>	<p>Continue with roof/wall bracing</p> <p>Rafters, loads and restraint conditions Discuss setting out / presentation of calculations.</p> <p><i>Project schedule - By 19 March, complete bracing design</i></p>	<p>MPR Bending members</p>
<p>4 (Mar 19, 20)</p>	<p>Continue with rafters - revise the load cases that need to be considered.</p> <p>Loads to columns Discuss restraint conditions of columns</p> <ul style="list-style-type: none"> <li>• Effective length for buckling</li> <li>• Restraint for bending</li> </ul> <p><i>Project schedule - By 26 March, beam designs completed, column loads determined.</i></p>	<p>MPR Bending members</p>

5 (Mar 26, 27)	Continue with columns  <i>Project schedule – By 2 April, column designs completed.</i>	MPR Combined Actions
6 (April 2, 3)	Discuss beam-column connection Discuss drawing presentation  <i>Project schedule – By 10 April, finish connection and drawings</i>	MPR Connections
April 10 (Mid Sem Break)	Project and Journal submission	
Mid Sem Break	Mark Projects, feedback sheets	
7 (Apr 23, 24)	Hand out project 2, read for questions, but can't do much yet.	Mon (2 hours) – What is reinforced concrete? Strength of beams in bending Tues (4 hours) • Double reinforced beams • T and L beams  Possible Friday pm session??? One way slabs, so they can start on project?
8 (Apr 30, May 1)	JEM away	
9 (May 7, 8)	At end of Tuesday session – short discussion on project questions, what they can start  <i>Project schedule – By 14 May, One way slab design</i>	Mon (2 hours) • Shear in beams Tues (3 hours) • One way slabs • Continuous beams
10 (May 14, 15)	Tues (2 hours) – two way slab design  <i>Project schedule – By 21 May, two-way slab design finished</i>	Mon (2 hours), Tues (1 hour) • Types of slabs • Design of slabs supported on 4 sides • Shrinkage and temperature
11 (May 21, 22)	Mon (public holiday), consultations on Tuesday afternoon or Friday? Beam designs  <i>Project schedule – By 28 May, beam design(s) finished</i>	Tues (3 hours) – Columns • Short • Interaction diagrams • Design charts
12 (May 28, 29)	Column designs  <i>Project schedule – By 28 May, column design(s) finished</i>	Tues (3 hours) • Serviceability and deflections of beams and slabs • detailing
13 (June 4, 5)	Drawings	Tues (3 hours) Finish deflection and detailing Slab footing introduction
June 12	Project and Journal submission	
	Mark Projects, feedback sheets	

**Appendix B7 - Curtin University of Technology  
Science and Mathematics Education Centre**

**Information and call for volunteers in an education research project titled:  
*The effectiveness of project-based learning in Structural Engineering***

Researcher: Mrs Julie Mills. Telephone (08) 8302 3073

As part of the research program for my PhD, being undertaken through Curtin University, I am conducting a case study of the course Building for People N, in Semester 1, 2001, to assist in determining the effectiveness of design projects for learning the concepts and practice of structural engineering. It is hoped that the research will assist in gaining a better understanding of the teaching and learning of structural engineering, which can be used to improve learning outcomes in this area at both the University of South Australia and other institutions.

In order to investigate the above topic, I would like to conduct strictly confidential interviews of 5 to 10 volunteers from the class. Depending on the number of volunteers and their preference, the interviews may either be conducted individually or in small groups. The date and time of interviews will be organised at the student's convenience, probably early in the break between semesters. The interviews will ask students about their perceptions of various aspects of the course Building for People N, including:

- What were the skills/concepts intended to be learned in the course?
- The effectiveness of the different teaching and learning strategies used in the course in developing these skills/concepts for them.
- Their opinions on the effectiveness of the design projects for learning in particular, and their relevance to future professional practice.

The interviews will take approximately 1 hour and will be recorded on audio tape. The tape will later be audited by the researcher and some parts of it may be transcribed for further study. Transcriptions will be available for checking and retention by the volunteer. The identity of the volunteers will be known only to the researcher and your identity will be protected at all times. In any reporting of the outcomes of the interviews, either in my doctoral thesis or in research conference or journal papers, names of the interviewees will be replaced by pseudonyms or alternative initials. Records of the interviews will be stored securely within the School of GMC, University of SA for a period of seven years, as required by the University.

Volunteers are free to leave the project at any time, without prejudice. Participation is entirely voluntary. Taking part in the study will not provide students with any advantage or disadvantage in relation to their own academic results. I guarantee that there will be no academic, personal or financial pressures on volunteers to take part. I am required to approach the project in a strictly impersonal manner, so I assure you that considered negative and positive responses are equally acceptable.

Before taking part in an interview, each volunteer will be asked to sign a Consent Form, a blank copy of which accompanies this sheet. Intending volunteers are invited to discuss the research with a relative or friend before signing the form. Please read this information sheet and the Consent Form carefully before you decide to take part. If you need more information from me, I can be contacted by phone (above), email [julie.mills@unisa.edu.au](mailto:julie.mills@unisa.edu.au) or in Room H3-14.

This research is being conducted with the approval of Curtin University's Human Research Ethics Committee and is also endorsed by the Head of the School of Geoscience, Minerals and Civil Engineering at the University of SA.

Volunteers are asked to return the signed Consent Form either personally to me, or in an envelope marked "Building for People N Research" to my pigeonhole or through the internal mail to Julie Mills, School of GMC, Building H, Mawson Lakes Campus. I would appreciate receiving replies by 30 April, 2001.

Thank you  
Julie Mills

**Curtin University of Technology  
Science and Mathematics Education Centre**

**Consent Form for the project:  
*The effectiveness of project-based learning in Structural Engineering***

Researcher: Mrs Julie Mills. Telephone (08) 8302 3073

Statement of consent by the subject (person to be interviewed)

1. I have read the Information Sheet and the nature and purpose of the research project has been explained to me. I understand and agree to take part.
2. I understand that I may not directly benefit from taking part in the study.
3. I understand that while information gained during the study may be published, I will not be identified and my personal results will remain confidential.
4. I understand that I can withdraw from the study at any stage and that this will not affect my status now or in the future.
5. I have had the opportunity to discuss taking part in this study with a family member or friend.
6. I confirm that I am over 18 years of age.

Name of subject

\_\_\_\_\_

Signed

\_\_\_\_\_

Date \_\_\_\_\_

Statement by researcher:

I certify that I have explained the study to the volunteer subject and consider that he/she understands what is involved.

Signed

\_\_\_\_\_

Date \_\_\_\_\_

## Appendix B8 - Course Evaluation Questionnaire - Building for People N 2001

The purpose of this questionnaire is to collect student opinions on various aspects of this course. Your responses will be used by the lecturer(s) as a basis for improving the teaching of this course. Please circle the number that most closely corresponds to your view about each statement, using the scale provided. If you feel that you cannot answer a particular question, circle 'X' in the 'Not Applicable' category. All responses are anonymous.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Not Applicable
1	2	3	4	5	X

1. It was clear what was expected of me in this course	1	2	3	4	5	X
2. The tasks that I was given to do helped me to achieve the learning objectives of this course	1	2	3	4	5	X
3. The staff teaching in this course showed a genuine interest in their teaching	1	2	3	4	5	X
4. The projects were returned in a reasonable amount of time	1	2	3	4	5	X
5. It is clear to me that the assessment methods in this course require me to understand the material that has been presented	1	2	3	4	5	X
6. The feedback I received on my work has been constructive and helpful	1	2	3	4	5	X
7. The teaching staff in this course did their best to help me progress	1	2	3	4	5	X
8. I was generally able to obtain help when I needed it outside of the regular class hours	1	2	3	4	5	X
9. The workload for this course was reasonable given my other study commitments	1	2	3	4	5	X
10. The course enabled me to develop and/or strengthen a number of the qualities of a University of South Australia graduate	1	2	3	4	5	X
11. There was generally enough time to understand the things we have to learn	1	2	3	4	5	X
12. The lecturer(s) shows an interest in the students	1	2	3	4	5	X
13. The teaching methods used in this course suit the way I prefer to learn	1	2	3	4	5	X
14. I can see the relevance of this course for my degree program	1	2	3	4	5	X
15. The content of the course was consistent with the course outline	1	2	3	4	5	X
16. In this course I have been encouraged to develop my own learning skills	1	2	3	4	5	X
17. This course has an appropriate balance between increasing my knowledge and developing my ability to apply that knowledge effectively	1	2	3	4	5	X
18. The knowledge and skills gained in this course will prepare me well for my future career	1	2	3	4	5	X
19. The assessment methods in this course enable me to best demonstrate what I have learnt	1	2	3	4	5	X
20. Overall I am satisfied with the quality of this course	1	2	3	4	5	X

**21. Which specific aspects of the course have you found most useful for your own learning? Why?**

**22. Please use the space below to comment on any other aspects of the course, including any suggested changes.**

## Appendix B9 - BUILDING FOR PEOPLE N - Perceived curriculum evaluation

June, 2001

Imagine that immediately following graduation, you are employed as a graduate Structural Engineer in the structural design team of a consulting firm such as Connell Wagner or Ove Arup. Please answer the following questions based on the scale:

Very unimportant	Unimportant	Neutral	Important	Very important	Not applicable
1	2	3	4	5	X

A. How important do you believe the following general skills and attributes will be in this position?

1. Ability to apply knowledge of basic science and engineering fundamentals.	1	2	3	4	5	X
2. Ability to communicate effectively, not only with engineers but also with the community at large.	1	2	3	4	5	X
3. In-depth technical competence in structural engineering	1	2	3	4	5	X
4. Ability to undertake problem identification, formulation and solution.	1	2	3	4	5	X
5. Ability to utilise a systems approach to design and operational performance.	1	2	3	4	5	X
6. Ability to function effectively as an individual and in multi-disciplinary and multi-cultural teams, with the capacity to be a leader or manager as well as an effective team member.	1	2	3	4	5	X
7. Understanding of the social, cultural, global and environmental responsibilities of the professional engineer, and the need for sustainable development.	1	2	3	4	5	X
8. Understanding the principles of sustainable design and development.	1	2	3	4	5	X
9. Understanding of professional and ethical responsibilities and commitment to them.	1	2	3	4	5	X
10. Expectation of the need to undertake lifelong learning and capacity to do so.	1	2	3	4	5	X

B. How important do you believe the following technical skills or abilities will be in this position?

11. Understanding of the importance of all three basic principles of structure – stability, strength , serviceability.	1	2	3	4	5	X
12. Understanding loads (gravity, wind etc.) and how their effects are modelled in structural analysis.	1	2	3	4	5	X
13. Understanding the need to produce engineering solutions that are functional and economical as well as technically correct.	1	2	3	4	5	X
14. Having good knowledge of the properties of each of the materials normally used – steel, concrete.	1	2	3	4	5	X
15. Understanding the need for alternative load paths and the need to avoid progressive collapse mechanisms.	1	2	3	4	5	X
16. Having the ability to “visualise” failure mechanisms.	1	2	3	4	5	X
17. Having a good knowledge of modern techniques of structural analysis, design and construction.	1	2	3	4	5	X
18. Having a broad knowledge of relevant Australian standards.	1	2	3	4	5	X
19. Having knowledge of available analysis and design aids including computer programs and design manuals.	1	2	3	4	5	X
20. Having short-cut methods to check computer program outputs.	1	2	3	4	5	X
21. Having the ability to communicate design solutions through sketches and engineering drawings						

PLEASE TURN OVER, MORE QUESTIONS ON THE BACK



- C. Where do you believe that you gain skill or knowledge in these areas in the course Building for People N (noting that not all of the areas may be covered in this course)? Please tick boxes in each line (you may have from 1 to 3 ticks in any line).

	Lectures/ Tutorials/ Practicals (formal contact hours)	Design Project (formal contact and outside hours work)	Self-study (any other work outside formal contact hours)	No opportunity in this course
22. Ability to apply knowledge of basic science and engineering fundamentals.				
23. Ability to communicate effectively, not only with engineers but also with the community at large.				
24. In-depth technical competence in structural engineering				
25. Ability to undertake problem identification, formulation and solution.				
26. Ability to utilise a systems approach to design and operational performance.				
27. Ability to function effectively as an individual and in multi-disciplinary and multi-cultural teams, with the capacity to be a leader or manager as well as an effective team member.				
28. Understanding of the social, cultural, global and environmental responsibilities of the professional engineer, and the need for sustainable development.				
29. Understanding the principles of sustainable design and development.				
30. Understanding of professional and ethical responsibilities and commitment to them.				
31. Expectation of the need to undertake lifelong learning and capacity to do so.				

Continued next page

	Lectures/ Tutorials/ Practicals (formal contact hours)	Design Project (formal contact and outside hours work)	Self-study (any other work outside formal contact hours)	No opportunity in this course
32. Understanding of the importance of all three basic principles of structure – stability, strength, serviceability.				
33. Understanding loads (gravity, wind etc.) and how their effects are modelled in structural analysis.				
34. Understanding the need to produce engineering solutions that are functional and economical as well as technically correct.				
35. Having good knowledge of the properties of each of the materials normally used – steel, concrete.				
36. Understanding the need for alternative load paths and the need to avoid progressive collapse mechanisms.				
37. Having the ability to “visualise” failure mechanisms.				
38. Having a good knowledge of modern techniques of structural analysis, design and construction.				
39. Having a broad knowledge of relevant Australian standards.				
40. Having knowledge of available analysis and design aids including computer programs and design manuals.				
41. Having short-cut methods to check computer program outputs.				
42. Having the ability to communicate design solutions through sketches and engineering drawings				

## Appendix B10 - Project 1 – allocation of marks to generic and technical skills

Item – Project 1	Allocated %	Skill type & No.
<b>Wind load determination, consisting of:</b> <ul style="list-style-type: none"> <li>• Design wind speed</li> <li>• External pressures</li> <li>• Internal pressures</li> </ul>	<b>14</b> 3 7 4	T12(b)
<b>Overall building stability under wind i.e. roof and wall bracing, consisting of:</b> <ul style="list-style-type: none"> <li>• layout and member load determination</li> <li>• tension members design</li> <li>• compression members design</li> </ul>	<b>10</b> 4 3 3	T11(b) & T17(d) T11(b) & T17(d) T11(b) & T17(d)
<b>Rafter, R1 design, consisting of:</b> <ul style="list-style-type: none"> <li>• determine design loads for strength &amp; serviceability</li> <li>• serviceability design</li> <li>• strength design - section moment capacity</li> <li>• strength and stability design - member moment capacity (including effective lengths) for worst up and down load combinations</li> </ul>	<b>15</b> 5 3 2 5	T12(b) T11(b) & T17(d) T11(b) & T17(d) T11(b) & T17(d)
<b>*Ridge Beam, RB1 design, consisting of:</b> <ul style="list-style-type: none"> <li>• determine design loads for strength &amp; serviceability</li> <li>• serviceability design</li> <li>• strength design - section moment capacity</li> <li>• strength and stability design - member moment capacity (including effective lengths) for worst up and down load combinations</li> </ul>	<b>8</b> 2 2 1 3	T12(b) T11(b) & T17(d) T11(b) & T17(d) T11(b) & T17(d)
<b>Column design C1, consisting of:</b> <ul style="list-style-type: none"> <li>• determine axial loads and bending moments</li> <li>• strength design – tension (uplift)</li> <li>• strength and stability design - compression</li> <li>• strength and stability design - bending</li> <li>• strength and stability design - combined actions</li> </ul>	<b>15</b> 3 2 3 3 4	T12(b) T11(b) & T17(d) T11(b) & T17(d) T11(b) & T17(d) T11(b) & T17(d)
<b>*Column design C2, consisting of:</b> <ul style="list-style-type: none"> <li>• determine axial loads and bending moments</li> <li>• strength design – tension (uplift)</li> <li>• strength and stability design - compression</li> <li>• strength and stability design - bending</li> <li>• strength and stability design - combined actions</li> </ul>	<b>12</b> 2 2 2 2 4	T12(b) T11(b) & T17(d) T11(b) & T17(d) T11(b) & T17(d) T11(b) & T17(d)
<b>Rafter R1- Column C1 connection for worst case</b> <ul style="list-style-type: none"> <li>• bolt design</li> <li>• weld design</li> </ul>	<b>6</b> 4 2	T11(b) & T17(d)
<b>Presentation and Drawings</b> <ul style="list-style-type: none"> <li>• Plan view with roof and wall bracing locations and all elements labelled</li> <li>• Member schedule giving details of each labelled member type</li> <li>• Rafter-column connection detail</li> <li>• Journal and overall presentation of calculations</li> </ul>	<b>20</b> 5 3 4 8	G2 & T21
<b>Total</b>	<b>100% x 0.20</b> =20 marks	

G = generic skill

T = technical skill (refer to achieved curriculum spreadsheet)

## Appendix B11 - Project 2 – allocation of marks to generic and technical skills

Item	Allocated %	Skill type & no.
<b>Slab Panel A (one-way):</b> <ul style="list-style-type: none"> <li>• Determine thickness for serviceability using Warner's method</li> <li>• Determine design loads, bending moments &amp; shears in accordance with Sec 7.2</li> <li>• Design reinforcement for bending, check minimum.</li> <li>• Design reinforcement for crack control etc.</li> </ul>	<b>11</b> 2 4 3 2	T11(b) & T17(d)  T12(b)  T11(b) & T17(d) T11(b) & T17(d)
<b>Slab Panel B (two-way):</b> <ul style="list-style-type: none"> <li>• Using same thickness as Panel A, determine design loads, bending moments to Sec 7.3</li> <li>• Design reinforcement for bending, both directions</li> <li>• Check reinforcement for crack control etc.</li> </ul>	<b>9</b> 3 4 2	T12(b) T11(b) & T17(d) T11(b) & T17(d)
<b>Beam CB1:</b> <ul style="list-style-type: none"> <li>• determine design loads for strength</li> <li>• determine design BM's and shears to Sec 7.2</li> <li>• Design reinforcement for +ve and -ve bending</li> <li>• Design reinforcement for shear</li> </ul>	<b>20</b> 5 4 6 5	T12(b) T17(b) T11(b) & T17(d) T11(b) & T17(d)
<b>*Beam CB2:</b> <ul style="list-style-type: none"> <li>• determine design loads for strength</li> <li>• determine design BM's and shears to Sec 7.2</li> <li>• Design reinforcement for +ve and -ve bending</li> <li>• Design reinforcement for shear</li> </ul>	<b>12</b> 4 2 4 2	T12(b) T17(b) T11(b) & T17(d) T11(b) & T17(d)
<b>Column C1 (between ground and first floor):</b> <ul style="list-style-type: none"> <li>• determine axial compressive loads and min BM's</li> <li>• determine whether short or slender</li> <li>• develop the column interaction diagram, assuming minimum steel, and check adequacy</li> <li>• check your design using column charts supplied</li> </ul>	<b>15</b> 4 2 7 2	T12(b) T11(b) & T17(d)  T11(b) & T17(d) T11(b) & T17(d)
<b>*Column C2 (between ground and first floor):</b> <ul style="list-style-type: none"> <li>• determine axial compressive loads and min BM's</li> <li>• determine whether short or slender</li> <li>• design using column charts</li> </ul>	<b>8</b> 4 2 2	T12(b) T11(b) & T17(d) T11(b) & T17(d)
<b>Drawings:</b> <ul style="list-style-type: none"> <li>• Plan view of Slab Panel B reinforcement</li> <li>• Beam CB1 elevation and critical sections</li> <li>• Elevation of slab panel A, CB1, Column C1 and indicative footing , to underside of roof, and section through Col C1</li> <li>• Journal and overall presentation of calculations</li> </ul>	<b>25</b> 3 7 7 8	G2 & T21
<b>Total</b>	<b>100% x 0.20 =20 marks</b>	

G = generic skill

T = technical skill (refer to achieved curriculum spreadsheet)

FIRST SEMESTER EXAMINATIONS, JUNE 2001

BUILDING FOR PEOPLE N

**GENERAL INSTRUCTIONS TO CANDIDATES:**

1. Attempt ALL questions.
2. Marks for questions are shown in brackets.
3. Please answer Parts A and B in separate books

Lecturer: J. Mills, M.  
Rajakaruna  
Course: LBMI / LBMP /  
LBEC  
Reading Time:  
10 mins  
Exam Duration:  
3 hours

4. You may use the following books/information:
  - SAA HB2.2 – Australian Standards for civil engineering students Part 2: Structural Engineering (purple, green or white edition)
  - BHP Hot Rolled and Structural Steel Products
  - Reinforcement Data Card – Smorgon ARC
  - A total of 2 double sided A4 pages with any notes, formulae, information etc you desire to include

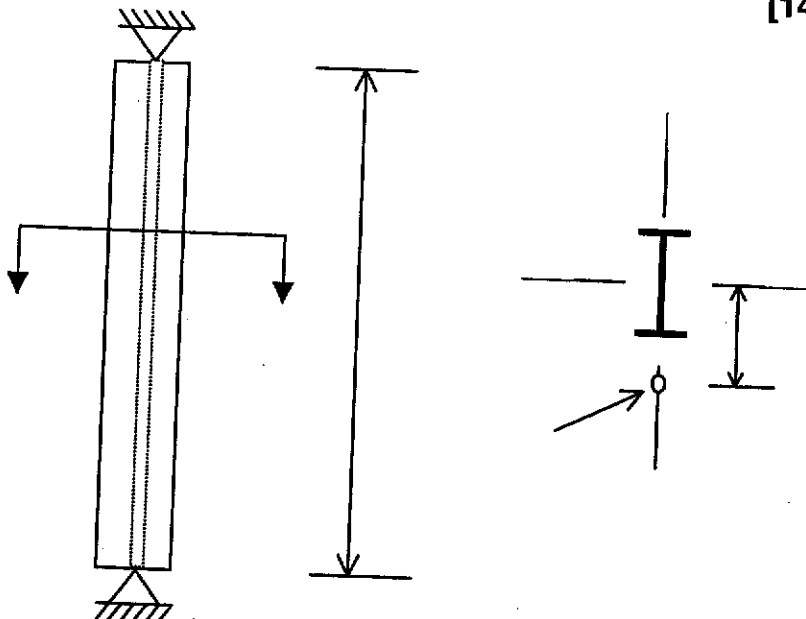
**PART A: Structural Steel Design [40 marks]**

**QUESTION 1**

Determine if the the column shown below can carry an ultimate load of 700kN in compression if the load is applied at an eccentricity of 200mm at both ends as shown.

The column section is a 250UC 72.9 (grade 300). The length of the column is 8m and it is pinned at both ends. Sufficient restraint is provided to ensure that the column is prevented from out of plane buckling.

**[14 marks]**



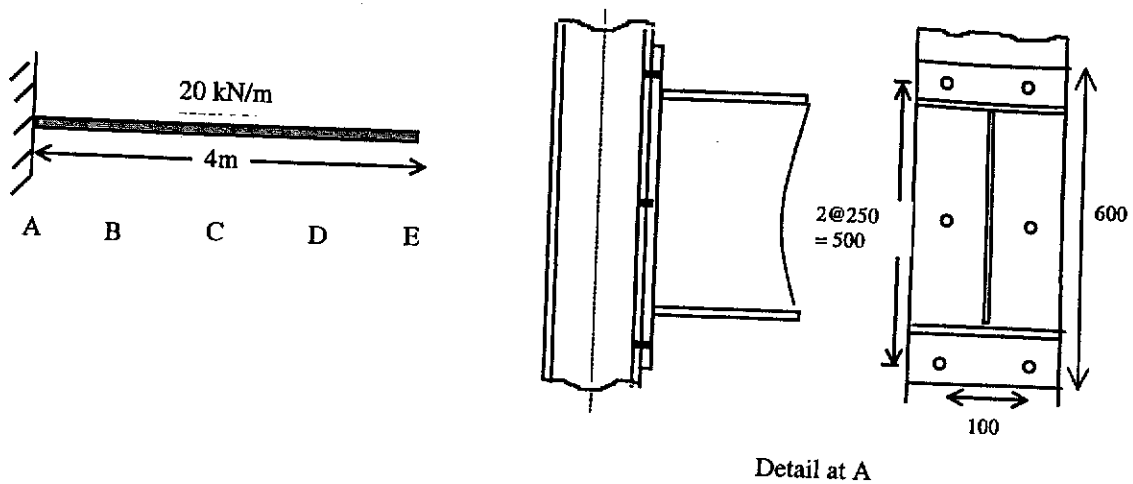
## QUESTION 2

a)

A steel cantilever beam is acted on by a distributed ultimate load of  $20\text{ kN/m}$  over its entire span as shown. The beam is fully restrained against lateral buckling at the points A, B, C, D and E spaced  $1\text{ m}$  apart. Determine if a  $360\text{UB } 44.7$  section (grade BHP-300PLUS) is adequate to carry this load.

Neglect the self-weight of the beam. The serviceability limit state need not be checked.

[16 marks]



b)

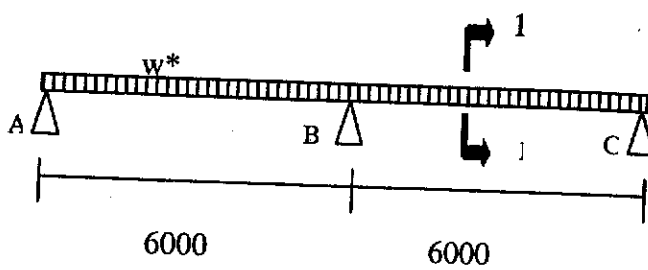
If the beam is connected to a  $360\text{UB } 44.7$  column at A with 6 bolts as shown in detail, determine a suitable bolt size for the connection. The bolts are grade 8.8S and the plate  $8\text{ mm}$  thick grade 300 steel (see Appendix A for bolt and plate capacities).

[10 marks]

**PART B: Reinforced Concrete Design [60 marks]**

**QUESTION 3**

A two-span reinforced concrete beam is detailed below.



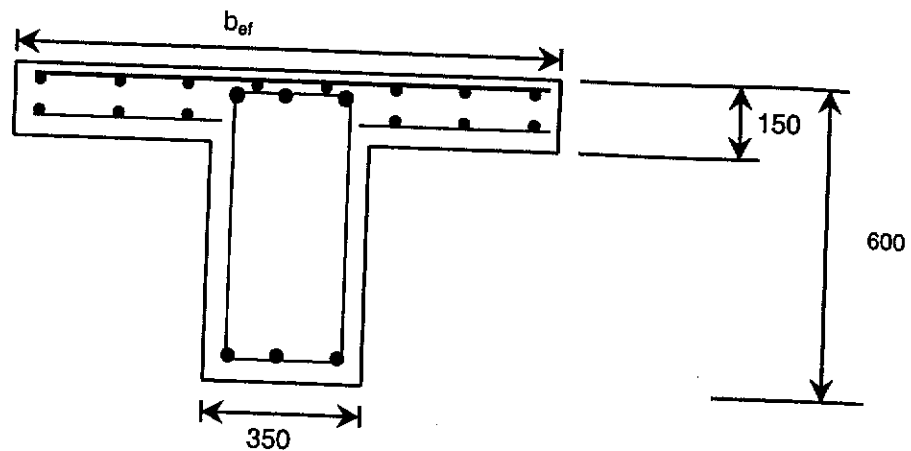
$g = 40 \text{ kN/m}$  (including self-weight)  
 $q = 25 \text{ kN/m}$

Column supports at A, B and C are  $350 \times 350$  square

$f'_c = 32 \text{ Mpa}$   
 $f_{sy} = 400 \text{ Mpa}$

Exposure classification = A1

Slab reinforcement is Y12 bars @ 300 cts, top and bottom, in both directions



Beam

reinforcement bar numbers are indicative only (i.e. you may have more than 3 bars top and bottom)

**SECTION 1-1**

- a) Sketch the shear force and bending moment diagrams using the Simplified Method of Section 7.2

**[10 marks]**

- b) Determine the required tensile steel,  $A_{st}$ , for the negative moment over support B, **neglecting** the presence of compressive steel in the beam. You may use an approximate expression to make an initial estimate of  $A_{st}$ , but you must determine the actual capacity by first principles.

**[15 marks]**

- c) Using this value of  $A_{st}$  (or 4 Y24 if you have been unable to determine a value), determine the shear ligatures required for the maximum shear force adjacent to support B. You may assume  $\cot \theta_v = 1$  and  $f_{syf} = 400 \text{ Mpa}$ .

**[12 marks]**

- d) Determine the total deflection at midspan using the simplified method of Section 8.5.3. You may use the simplified expression for T sections given in Section 8.5.3.1(c)(ii) and calculate only the value of  $l_{ef}$  at **mid-span** in this case. Also assume that  $A_{sc} = A_{st}$ . The end-span deflection for a continuous beam may be taken as

$$\Delta = \frac{1}{185} \frac{wL_{ef}^4}{EI}$$

Is this deflection acceptable?

[15 marks]

- e) **ONLY ATTEMPT THIS PART IF YOU HAVE COMPLETED THE REST OF THE PAPER**

Assuming  $A_{sc} = A_{st} = 4$  Y24 bars, determine the maximum design moment capacity of this beam at mid-span, taking into account the presence of both compressive and tensile steel, but neglecting slab steel. Do a **maximum of two** trial depths for the neutral axis. Show that the beam is ductile.

[8 marks]



Appendix A

9.1.3(b) Design Capacities of Commonly Used Bolts – Strength Limit State

HIGH STRENGTH STRUCTURAL BOLTS  
8.8/S, 8.8/TB, 8.8/TF BOLTING CATEGORIES

GRADE 8.8

TABLE 9.1.3(b): Design Capacities  
( $f_u = 830 \text{ MPa}$ )

Bolt Size	Axial Tension $\phi N_t$ kN	Single Shear		Plate Tearout in kN												Bearing in kN		
		Threads Included in Shear Plane $\phi V_{in}$ kN	Threads excluded from Shear Plane $\phi V_{ex}$ kN	$\phi V_b$ for $t_p$ & $a_o$ of:												$\phi V_b$ for $t_p$		
				$t_p = 6$			$t_p = 8$			$t_p = 10$			$t_p = 12$			6	8	10
		35	40	45	35	40	45	35	40	45	35	40	45	190	124	122	162	203
M16	104	59.3	82.7															
M20	163	92.6	129	83	95	107	111	127	143	139	158	178	186	190	124	152	203	253
M24	234	133	186															
M30	373	214	291															
M36	541	313	419															
		$\phi = 0.8$		$\phi = 0.9$												$\phi = 0.9$		
		8.8/S		$f_{up} = 440 \text{ MPa}$												$f_{up} = 440 \text{ MPa}$		

Note: The above table lists the design capacity of a ply in bearing for Grade 300 ( $f_u = 440 \text{ MPa}$ ) steel only. For listings and guidance on design capacities for ply failure in other grades of steel refer to Section 9.1.4.

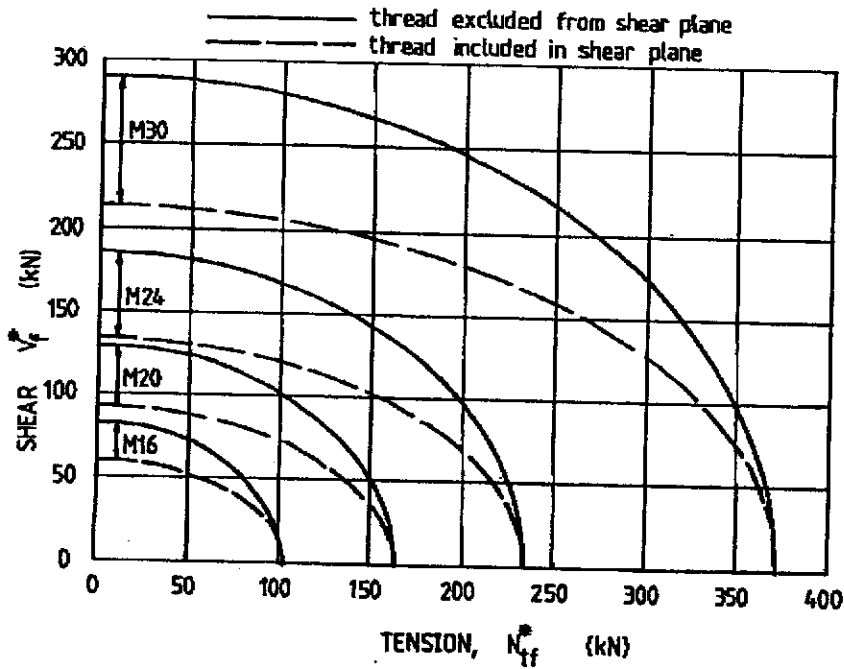


Figure 9.1.3(b): Shear – Tension Interaction Diagram

### Appendix B13 - Exam questions – allocation of marks to generic and technical skills

Question	Allocated %	Skill type & no.
Steel question 1 <ul style="list-style-type: none"> <li>Determine design load and bending moment</li> <li>Check section capacity, member capacity and combined actions</li> </ul>	14 2 12	T12(a) T11(a) & T17(c)
Steel Question 2(a) <ul style="list-style-type: none"> <li>Determine shear force and bending moment</li> <li>Design for shear, bending and interaction</li> </ul>	16 2 14	T17(a) T11(a) & T17(c)
Steel Question 2(b) <ul style="list-style-type: none"> <li>determine design moments and shears</li> <li>Design bolts and plate using AISC charts</li> </ul>	10 3 7	T17(a) T11(a) & T17(c)
Concrete Question 3(a) <ul style="list-style-type: none"> <li>determine design loads for strength</li> <li>determine design BM's and shears to Sec 7.2</li> </ul>	10 2 8	T12(a) T17(a)
Concrete Question 3(b) <ul style="list-style-type: none"> <li>reinforced concrete beam bending moment design</li> </ul>	15	T11(a) & T17(c)
Concrete Question 3(c) <ul style="list-style-type: none"> <li>reinforced concrete beam shear design</li> </ul>	12	T11(a) & T17(c)
Concrete Question 3(d) <ul style="list-style-type: none"> <li>determine serviceability load</li> <li>reinforced concrete beam serviceability design</li> </ul>	15 1 14	T12(a) T11(a) & T17(c)
Concrete Question 3(e) <ul style="list-style-type: none"> <li>analysis of beam capacity</li> </ul>	8	T17(a)
<b>Total</b>	<b>100% x 0.50 =50 marks</b>	

G = generic skill

T = technical skill (refer to achieved curriculum spreadsheet)

## **Appendix C**

Appendix C1: Video tapes of project sessions – focus sheet

Appendix C2: Extract from videotape observation records

Appendix C3: Lecturer/Researcher's activities during project sessions

Appendix C4: Extract from researcher's journal

## Appendix C1 - Video Tapes of Project Sessions

### Focus sheet - What am I looking for??

1. Do I dominate class too much, i.e. are they "lectures" rather than project sessions?

*Time the different activities on my part (this needs to be done with the journal because tapes only 60 mins long)*

2. What are the students doing in the class?

- Working alone
- Working in their project pairs
- Working with other groups
- Talking/mucking around, off-task

*Find the % time spent on these tasks? But this will vary for different students, do I try to follow particular individuals?*

3. My interaction with students e.g. time spent answering questions etc

### Possible approach??

For each session do the following:

- Who is in the picture? – draw a seating plan
- Broad timing of what happens in the class, e.g. 20 minutes lecture, 20 minutes of me circulating answering questions, rest working alone etc.
- General description of what happens in each session – time plot and noting of activities every 2 minutes say?
- Observation of each project group in picture and description of their activity for the session? *This would be very time consuming, would it be acceptable to just use some students as examples, maybe a range from across the results scale??*

## Presentation of this data:

- Use an overall description of the general approach of the sessions
- Table of my activities as % of the recorded time in each session (with notes to explain that only part of each session was recorded, could add a column to table that is my journal record of what happened in the rest of the session?). Also the average over all recorded sessions. Suggested categories for my activities would be:
  - Formal lecture
  - Interactive lecture, i.e. asking for and receiving responses from students to questions
  - Answering student questions in a whole class format
  - Working with individuals or small groups, checking progress, answering questions
  - Non-contact time (e.g. arranging camera/ cleaning board etc.)
  - Off-camera and audio, can't tell what I was doing
- Table of student activities as % of recorded time in each session and average over all recorded sessions. Table would be divided into individuals by initials on one axis, activities on other. Suggested categories for activities would include:
  - Listening to lecture, including taking occasional notes, checking text book etc
  - Off-task (and absent)
  - Working alone
  - Working with others
  - Asking questions in formal class
  - Asking questions, discussions with lecturer

## What does all of this data tell me????

- Are sessions different from formal lectures?
- Is my role different to normal lecturing?
- Do students use this time well – or maybe better phrased as “are students active learners in these sessions”?
- Is there a correlation between active participation in these sessions and good evaluation results for certain students and vice versa? (But does that mean anything anyway, because good students probably participate well in all activities in any course)

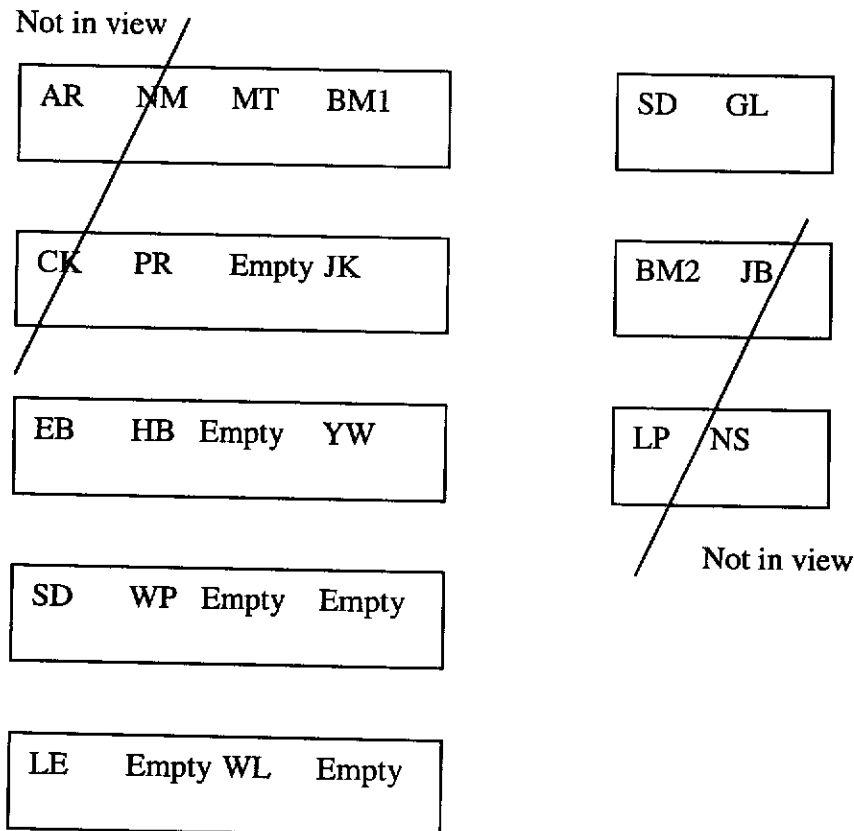
## Appendix C2 - Extract from videotape observation records

### Project 1 – 12 March 2001

From researcher's journal, the session started with a 20 minute site visit to the shed next to the lecture building from 1.10 pm to 1.30 pm, followed by a five minute talk from the lecturer on bracing.

Videotape commenced at approximately 1.35 pm.

### Seating Plan



Camera position  
at front of room

Absent: FL & JP at another class meeting

Note: JM are the researcher's initials

Elapsed time	Observation
00:10	JM enters scene to talk to students, had just been talking to class
01:00	JM asks about textbook availability – discussion with SD
01:41	EB leaves room
01:56	WL turns to talk to SD & WP “No, you’re wrong”, “Hey, turn around” Joking
02:40	JM goes to talk with MT, BM1 (they are working as a pair on project)
03:30	LP turns to talk to BM2

<b>Elapsed time</b>	<b>Observation</b>
03:57	EB returns. Students basically working and discussing quietly, assisting each other.
04:31	JM moves to talk to NM & AR (working as pair)
07:00	JM goes to talk to JK
09:30	AR gets up to talk to CK
11:00	NM leaves room
11:30	WL turns to see where JM is
11:50	JM moves to next pair – CK & PR
14:22	YW looked like she had a question for JM. WL calls to JM as she is moving to the next group – asks a question, JM goes to work with him
16:00	YW moves across to work with HB
16:10	As JM moves back, WP asks a question so JM goes there. LP working with BM2, waiting to ask a question.
16:50	JM returns to BM2 & JB where she was heading before to answer their questions
19:00	NM returns
19:30	YW moves back to her seat WL turns to discuss with WP again
20:00	Noise level slightly higher, more discussions
20:43	BM1 gives thumbs up, nods, “I understand” signals
21:20	CK gets up, appears to be looking for something, gets what he needs from BM1 and returns to seat, then up again (set of notes?)
22:30	WL pointing to something on the board. BM1 & MT appear to be chatting “off-task”. LE & WP discussing something, pointing to board.
23:00	YW comes across to listen to what JM is discussing with BM2 & JB
24:40	JM still discussing, demonstrating something to BM2
25:00	JM crosses back with YW and talks with her
27:37	JM has still not talked with LP, NS, EB & HB
30:00	JM drawing something for YW
33:50	NM leaves again JM demonstrating bracing to YW
34:20	MT leaves room JK gets up to talk to SD and ask him something
35:00	JM crosses to EB & HB
36:50	NM & MT return to room
37:00	JM goes to the front of the room to “Go through bracing again”, explains it is a difficult concept to get. Some students take approx 20 to 30 seconds to settle. JM drawing something on board.
38:10	JM asks class a question – some response from SK & WP. Some students go on with their work (WL)
41:40	JM asks another question, WP offers answer. JM asks another question, LP offers answer
42:45	JM asks another question, no answer after 4 secs – JM offers another suggestion, SK offers an answer
43:48	Another suggestion offered by NS, class discussion continues
45:50	LP asks a question about areas to use to calculate the truss, JM answers
47:20	JM mentions economics in design for the truss in a country like Australia where labour costs are more expensive, economics of repeating sizes and details to save time in design and fabrication. Class very attentive.
49:30	JM asks “OK?”, pauses for questions, none forthcoming. JM talks about what the experienced designer would do. “The whole thing about structural design is understanding the structural system so that you can do less design”

Elapsed time	Observation
50:54	JM "Are you clear about..? ... You're still looking puzzled."
51:30	Comment from NS offering suggestion, JM discusses in terms of economy.
52:30	JM waits for more questions – one from WP
53:30	JM talking about bracing as it appears in various types of buildings, WP continues the discussion with another question
55:00	NS asks something else and JM responds
56:00	JM explaining the concept of cross bracing to NS. Rest of the class starts to go on with their own work.
56:44	WP gets up to discuss something with JM on the board, CK goes up the front also. JK gets up to talk to SD
57:40	WP goes back to seat
58:40	JM talking with LP & NS
59:06	NM leaves room again AR gets up to chat with PR
59:35	WP, SK, WL talking about emailing, off task
1:00:20	WP gets up to leave
1:01:10	JM goes across to SK & WP. WP leaves room. WL listens in.
1:03:30	BM1 gets up to talk to AR
1:04:10	NM returns again and leaves with a paper
1:04:36	PR leaves, WL asking questions to JM CK, NS and AR leave
1:05:00	End of tape

From researcher's journal, the class concluded shortly after the tape finished.



**Project 2 – 7 May 2001**

Videotape commenced at approximately 1.15 pm.

**Seating Plan**

Not in view

~~BM2 JB Empty LE~~

EmptyEmpty

~~PR AR CK JP~~

Empty JK

Empty LP HB EB

~~GL SD~~

Not in view

FL MT NS YW

Empty WP SK WL



Camera position  
at front of room

Absent: BM1 & NM

Note: JM are the researcher's initials

Elapsed time	Observation
00:22	JM reminds class about practicals and the students advise her how MPR has organised it. JM advised that she will be available for consultation by students not doing the pracs since next Monday project class will not be held due to public holiday
01:10	SK & WL in discussion together MT, NS, FL, YW in discussion together AR off task, CK off task
02:00	JM enters picture, gives something to BM2, starts answering questions. Class group discussions continue
03:00	FL moves seats back to near BM2. CK, AR, PR leave, JK arrives
04:14	JM "Just one point that a couple of people have already asked about regarding the slab..". JM goes to the front to explain
05:09	JM returns to answer questions at the rear of the room

Elapsed time	Observation
06:00	BM2 moves to talk with FL and LP. Students working in their pairs and with other pairs. Discussions continue.
08:30	JM goes to the front of room. JK follows with a question.
08:53	JK returns to his seat (after collecting his first project marked, first time he has been in class since the second project started) JM talking to GL and SD.
09:45	SK, WP & WL chatting "off-task"
10:06	JP leaves room
10:25	JK gets up and talks to? (out of picture) behind him JM still talking to GL & SD
11:30	JP returns
11:40	JK leaves then comes back. WP getting louder
12:40	JP and JK leave class. SK, WP & WL still off-task and getting louder. JM talks with MT, LE
14:06	WP playing with camera, "looking for a zoom button to get a close up of (SK)". MT leaves class. JM talking with LE.
15:57	FL leaves class with bag
17:10	JM returns to front of class, out of picture
18:35	LP & BM2 pack up, BM2 leaves. SK, WP & WL still off task "That's not on is it? It's not recording is it?" from SK
20:10	JM goes to HB & EB
20:40	SK, WP & WL start work! Discussing reinforcement tables
21:03	LE, LP leave class
22:00	YW & NS turn around to join discussion with HB & EB
23:00	SK, WP & WL off task again! Waiting to ask their questions
30:00	JM still working with YW, NS, HB & EB. SK, WP & WL still off task. Only other students remaining in class are GL & SD working quietly together
31:00	WP asks JM a question about when they are doing the next topic in the lectures. SK asks a question to JM re slabs. WP & WL listen and then join discussion
36:20	JM still discussing with SK. WP & WL. Other groups of 4 and 2 students still working in their groups.
39:30	JM answering WL and SK questions
41:50	Question to JM from NS
42:50	WP packed up, SK packing. JM asks WP "How's the baby going?" (WP and wife had a baby a month before). Chat continues re settling babies.
46:50	WP b& SK leave. 6 students left working quietly. JM starts to pack up.
50:00	JM leaves room to get a drink, students remain working quietly
50:46	JM returns. Question to JM from GL
54:00	Quiet conversations, some chatting and jokes, but students still working
57:00	Question to JM from EB, JM goes to that group. Question from NS
1:02:00	Students continue working in groups
1:05:00	End of tape

**Appendix C3 – Lecturer/researcher's activities during project sessions (from video observations, supplemented by my journal recordings)**

Date (All 2001)	Time	Broad description of session	Lecturer/researcher's activities (in minutes:secs, then % of session)						
			Total dur'n (mins)	Formal lecture	Interactive lecture	Working with individuals or small groups	Non-contact (admin, set-up etc.)	Not on tape or recorded in journal	Other
5 March	1:10 to 2:45	Opening talk, circulating to groups, back to board twice for short periods to discuss things raised by several students or tips for next stage of work, then further circulating around students.	95 100%	22 23.2	5:45 6.0	52:15 55.0	5 5.3	10 10.5	0
12 March	1:10 to 3:00	Site visit to shed for first 25 minutes (not on tape). All then working in pairs/groups with me circulating for 35 minutes. Then informal lecture for 20 minutes and answering questions.	110 100%	10 9.1	21 19.1	44 40.0	5 4.5	5 4.5	25 22.7
19 March	9:10 to 9:56	Rescheduled and shortened class and all had a "Rocks" test immediately after class, so many absent. Informal lecture most of the session, then circulating to answer a few questions at the end.	46 100%	6:30 14.1	26 56.5	12:30 27.2	1 2.2	0 0	0 0
26 March	1:10 to 2:20	Session was consultations for first 35 minutes, then a class discussion for a few minutes. Then an interactive lecture with part of the group who weren't present the week before, while others continued working.	70 100%	0 0	30 42.9	39 55.7	1 1.4	0 0	0 0
3 April	12:10 to 1:30	Interactive lecture first 35 minutes or so, then circulating for queries for rest of session.	80 100%	0 0	33:30 41.9	45 56.3	1:30 1.8	0 0	0 0
7 May	1:10 to 2:15	Consultation session	65 100%	0 0	1 1.5	57 87.7	3 4.6	4 6.2	0 0
14 May	1:10 to 2:00	Consultation session	50 100%	0 0	8 16.0	36 72.0	1 2.0	5 10.0	0 0

Date (All 2001)	Time	Broad description of session	Lecturer/researcher's activities (in minutes:secs, then % of session)						
			Total dur'n (mins)	Formal lecture	Interactive lecture	Working with individuals or small groups	Non-contact (admin, set-up etc.)	Not on tape or recorded in journal	Other
28 May	1:10 to 1:55	Consultation session	45	0	1	41	3	0	0
			100%	0	2.2	91.1	6.7	0	0
5 June	12:30 to 2:00	Session not taped, journal record indicates completely consultation session.	90	0	0	90	0	0	0
			100%	0	0	100	0	0	0
TOTAL			651	38:30	126:15	416:45	20:30	24	25
			100%	5.9	19.4	64.0	3.1	3.7	3.8

## **Appendix C4 - Extract from Researcher's Journal**

Note: The entries reproduced below are from the same days as the videotape observation records extracts. However, journal entries were also made on many days other than the project session days.

*12 March 2001*

Attendance 19/21

Opened session with walk to the shed next door (AITC). Pointed out items such as girts, purlins, bridging, mullions and end connections, portal frame connections, fly braces, sarking and sisalation. Focussed mainly on explaining the bracing system including roof and wall bracing as visible in the shed (shed has single tube SHS braces rather than crossed angle braces).

Questions asked included one about fire in steel buildings – will bring in photo of Sturt basketball stadium fire next week. Approx 20 minutes.

Back in N1-12 explained how to resolve the horizontal force into brace members using similar triangles then circulated for consultation. Tape started now.

Still about 2 to 3 people to get a copy of HB2.2 but at least 1 copy per pair now and I have lent mine to YW. Text books still awaited.

Progress/comments to date for pairs:

NM & AR: Have done all wind load coefficients, explained to them how they could put  $C_{pe}$  and  $C_{pi}$  on one sketch. Going OK.

BM1 & MT: Talked with them twice this session, have finished their wind loads and now done bracing layout and calculated bracing forces. Seem to both be getting the idea re bracing.

CK & PR: PR is very quiet, hasn't asked or said anything yet that I remember. Didn't have any queries first round, CK asked a question re bracing later. Not sure of their understanding to date.

JP & FL: Not present at this session.

BM2 & JB: JB quiet, doesn't say much. BM2 is getting some advice from his workplace (a small consulting firm) and seems to be quite keen on the project. Has some background in fabrication and seems to have a pretty good idea of things, not sure about JB.

EB & HB: Working well together, getting there. Up to bracing, finished wind loads. Similar stage and understanding to BM1 & MT.

GL & SD: GL is unable to attend 1 to 3 normally due to work. Have organised to see him approximately 12.00 on Tuesdays instead. They have also only just got HB 2.2 so still doing wind loads.

LE & WL: WL asking plenty and demonstrating good understanding, LE is quieter. Seem to both be contributing but WL leading the way.

WP & SK: Most advanced in class in terms of completion and understanding. Sizing their bracing and asking re fabrications and connections etc. of it.

NS & LP: Working well together. Both focussing on gaining full understanding and I think both succeeding. NS is quite a lateral thinker and questions demonstrate this. Completing bracing.

JK: Major concerns here as expected. Least advanced with respect to progress and probably understanding also. Has no partner to work with which is a problem. Only other person unpartnered is YW. I don't think it is fair to pair a fairly intimidating Fijian male with a newly arrived, quiet Chinese Malay female. Also his academic performance is terrible, hers excellent in UCS Diploma.

He is tending to work (copy from?) SD, JP & FL. This means he is getting some cooperative support in class (although I think annoying them/ slowing them but they are too nice to say anything) but presumably working alone outside class. He is still working out wind load coefficients, will struggle with bracing for sure.

Will try to provide additional time to him in class to compensate and encourage him to come with questions outside class time.

YW: Also struggling at this stage but to a much lesser extent. Completing wind loads. Has started to listen in to others' consultations but not working with others as JK is. Have spent extra time with her and encouraging her to come and ask questions outside of class.

Consultations approximately 1.20 to 2.00

Then had another session at board re bracing – explaining 2 separate systems for 2 perpendicular directions. Some had light bulbs go on, others still in the dark. Also talked about some of the economic realities – save \$ by repeating details, using the same members – not sizing each to the minimum possible. Could design each brace but no point – design worst cases and use throughout.

Did not get to rafter loads – no-one is there yet and they have not started bending lectures until tomorrow. Did illustrate/demonstrate load widths to rafters, loads to rafters in the shed.

Next week only 1 hour session 9.00 to 10.00 due to my personal leave.

7 May 2001

SK came to see me with some questions first thing in morning. He has done the reading and RC Aus as well as attempted all of Slab panel A. Said he felt that the RC Aus was a good complementary learning tool to the text and that my notes summarised things well. Also said that the project was "where things came together for him" and was "very important". His queries related to slab depth using Warner and how to interpret  $\text{mm}^2/\text{mm}$ .

Project session 1 to 3

Approximately 6 not there and 3-4 others left not long after the start as they had not yet attempted the project so had no questions.

Several pairs seem to have altered since first project – I asked NS/LP/WL to sort out something with YW, so NS is working with her and they are working with HB & HB too. LP has paired with BM2 (who had decided to work on his own before LP asked, so maybe JB didn't contribute much). That pairing should work well. LE said he wants to do on his own and seems to be working hard, so that is good. MT doesn't want to pair with BM1 and things BM1 & NM will pair up (I suspect they are an item??) so she will ask AR. WL will have rugby commitments and be away some of the time so wants to work on his own. CK & PR weren't there.

Questions/ progress in class

LE: Had made good attempt at Slab A. Question re interior vs exterior panel in Warner's equation which was shared by others in class so I answered generally. Also questions re reinforcement per m and "clear span".

He also came to see me again after class when he had reworked his numbers after earlier answers and is well on track.

JP & FL: Not started, left early.

BM2 & LP: Not started, left early.

SD & GL: Slab design for panel A fairly complete, similar questions to SK.

EB & HB, NS & YW: Both pairs at similar stage, good attempt at Slab A, similar questions to others. Later discussion showed a misunderstanding re which wall plan was above and below the slab.

SK & WP: Slab A design almost complete. SK has done work to date due to WP's new baby and grandmother's death last week. But they have resolved to split remainder of work.

## **Appendix D**

Appendix D1: Building for People N – Course evaluation results

Appendix D2: Building for People N – Course evaluation comments

Appendix D3: Perceived curriculum evaluation – student and industry ratings with Wilcoxon-Mann-Whitney test

Appendix D4: Building for People N – Overall assessment

Appendix D5: Achieved curriculum analysis



Course evaluation instrument overall results and reliability analysis (20 items, 21 respondents)

Student	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12
A	3	5	x	5	4	5	5	5	4	x	4	4
B	4	3		4	5	3	3	4	2	3	2	4
C	3	3	4	4	3	4	3	4	1	4	3	3
D	4	4	4	5	5	5	4	4	3	4	2	4
E	4	4	5	5	4	5	4	4	3	4	3	4
F	4	3	5	5	4	4	4	5	2	4	2	5
G	4	4	5	5	5	5	5	5	5	5	2	5
H	4	5	5	3	5	3	5	5	4	5	2	4
I	5	4	5	4	5	4	4	4	4	4	4	4
J	4	4	4	4	4	4	4	4	3	3	3	4
K	3	4	4	4	5	5	5	4	3	4	2	4
L	4	3	4	5	4	3	3	4	3	4	4	4
M	5	5	5	5	5	4	5	4	4	5	4	5
N	5	5	5	5	5	5	4	4	4	4	4	4
O	4	4	4	4	5	5	4	5	4	5	5	5
P	4	4	5	5	5	4	4	5	4	4	5	5
Q	4	5	5	5	4	4	4	4	4	4	4	4
R	5	5	5	5	5	4	5	4	5	5	5	5
S	5	5	5	4	5	3	5	4	4	x	3	4
T	4	4	4	4	4	5	4	5	4	4	3	4
U	5	5	5	5	5	4	4	3	2	3	3	5
ITEM MEANS	4.14	4.19	4.63	4.52	4.57	4.19	4.19	4.29	3.43	4.11	3.29	4.29
ITEM ST.DEV	0.65	0.75	0.50	0.60	0.60	0.75	0.68	0.56	1.03	0.66	1.06	0.56
ITEM VARS.	0.43	0.56	0.25	0.36	0.36	0.56	0.46	0.31	1.06	0.43	1.11	0.31
SUM ITEM VA	9.81											
TEST MEAN	82.48											
TEST STD. DE	8.08											
TEST VAR.	65.26											
K (# ITEMS)	20.00											
K-1	19.00											
CRONBACH'S												
ALPHA	0.89											
Standard Error of Measurement =	(Std.Dev. Of Test)(Sq. Root of 1-Cronbach's alpha)											
Standard Error of Measurement =							2.62					
95% C.I. for 1st person (upper limit) =							83.14					
95% C. I. for 1st person (lower limit) =							72.86					
95% C.I. for 10th person (upper limit) =							81.14					
95% C. I. for 10th person (lower limit) =							70.86					
95% C.I. for 20th person (upper limit) =							85.14					
95% C. I. for 20th person (lower limit) =							74.86					
95% C.I. For a person scoring at the test mean (upper li							87.62					
95% C.I. For a person scoring at the test mean (lower li							77.33					



## Appendix D2 - Course evaluation comments – Building for People N - 2001

1. Which specific aspects of the course have you found most useful for your own learning? Why?

Comment	Respondent	Average
	A	4.3
The lecture notes given out and examples that we have gone through. It does allow you to understand hard topics easier	B	3.6
	C	3.4
<ul style="list-style-type: none"> <li>Lecture notes and book (Warner) – well set out</li> <li>Still haven't tried computer program yet</li> <li>Summaries of design procedures in lecture notes most useful for design projects</li> </ul>	D	4.3
Most of the course were tasks to complete at your own rate, which was good for increasing organizational skills	E	4.1
The way of putting together a professional set of calculations as that which was done in the two major projects.	F	3.6
The projects for design are very practical and help to reinforce the theory. Tutorial problems help to reinforce concepts learnt in lectures.	G	4.5
The projects and the practicals are very useful to demonstrate the ideas discussed in class.	H	4.1
The projects as they ensured you had to do all aspects of the work throughout the subject.	I	4.2
Design project – enables a good concept of knowledge and application to be practiced.	J	3.8
The lecture handouts were helpful especially having worked examples in the concrete section. The Code was confusing and I thought maybe a bit more time could be spent learning to use it. Although once learnt it was easier to work through.	K	4.2
Most of the course, because one topic led to another one so it was interesting all through.	L	3.8
Being able to apply most of the work in the real world.	M	4.8
	N	4.6
The projects because they offer a step by step approach to completing the tasks.	O	4.5
	P	4.5
I have found the project based learning most useful as it provides a realistic application of knowledge acquired, and an effective learning regime.	Q	4.3
Design projects ⇒ good, help to apply what we have learnt in lectures. Practical help “visualise failure mechanisms”	R	4.8
	S	4.4
	T	4.0
	U	4.2

2. Please use the space below to comment on any other aspects of the course, including any suggested changes.

Comment	Respondent	Average
If there is more magazines or resources can be found in library will be better. Like relevant references.	A	4.3
Longer time for projects. Having the lectures before doing practicals would be useful in understanding what is going on with columns. The practical should reinforce information from the lecture to understand this information a lot better.	B	3.6
International students especially Torrestraits (sic) Islander or older students should be put to work in Groups when doing project work. I find it very hard working Individually because I have forgotten most of the staff (sic).	C	3.4
<ul style="list-style-type: none"> <li>• Bit weird that had columns prac, and had to hand them in, before had actual lecture on columns.</li> <li>• Very hard to be lectured on a topic and then expected to apply it straight away to design project</li> </ul>	D	4.3
It would be good to see a site visit to a construction site organised early in the course before most of the theory has been introduced, that way the practical side is easier to understand.	E	4.1
I would consider making steel design in a one semester course and the same with concrete design ie Steel Design – Sem 1, Concrete Design – Sem 2.	F	3.6
At times the course was progressing a little too fast for me to learn and understand the topics.	G	4.5
Site visits in both steel and concrete either early on or later in semester to help visualising the ideas and concepts.	H	4.1
	I	4.2
[MPR] was difficult to get extra information out of. He is difficult to understand and seems to brush you off.	J	3.8
	K	4.2
Maybe the projects can have less work load	L	3.8
That more time was taken to explain what exactly was required for practicle (sic) write-ups. Other than that the rest of the subject is great.	M	4.8
I thought the project approach was particularly useful. It was well thought out and presented but at the same time required us to really think and forced us to apply what we had learnt. The concrete practicals were too rushed and there was no feedback from the first report prior to writing and handing up the second one.	N	4.6
Provide the correct practical sheets at the beginning of the practical not a couple of days before it's due. Maybe a bit more time to write the practical up. The 1 <sup>st</sup> practical only had 3 days to complete quite a lengthy report.	O	4.5
	P	4.5
Extended times re due dates of practicals	Q	4.3
	R	4.8
Could [MPR] please reply to emails with questions about pracs and tuts.	S	4.4
It would be nice if [MPR] got back to emails I sent him in regards to an assignment (when I could not find him in his office) – not once did he get back to me so I had to ask students	T	4.0

about the work instead. [MPR] assumed we knew too much an in my case, I got "lost" with a few aspects which led to my falling behind in the understanding of perhaps a vital part of a question etc. – when asked to explain, he simply repeated the same thing and again I turned to students for help.		
	U	4.2

### Appendix D3 – Perceived importance of generic and technical skills for student and industry groups

(Ranking within the group in parentheses), with Wilcoxon-Mann-Whitney significance test results.

Skill	Student response (n = 21)	Industry response (n = 9)	z	p	Significant rank difference at $\alpha = 0.05$ ?
<b>Generic skills</b>					
1. Apply fundamentals.	4.2 (5=)	5.0 (1)	3.24	0.0007	Yes
2. Communication.	4.6 (1)	4.8 (2=)	1.25	0.1056	No
3. Technical competence.	4.2 (5=)	4.1 (7)	0.54	0.2946	No
4. Problem solving.	4.4 (2)	4.8 (2=)	1.83	0.0336	Yes
5. Systems approach.	4.1 (7=)	3.3 (9=)	-3.22	0.0007	Yes
6. Teamwork.	4.3 (3=)	4.6 (4=)	1.28	0.1003	No
7. Social & environment.	4.0 (10)	3.3 (9=)	-1.51	0.0655	No
8. Sustainable design.	4.1 (7=)	3.4 (8)	-1.83	0.0336	Yes
9. Ethics.	4.1 (7=)	4.4 (6)	1.25	0.1056	No
10. Lifelong learning.	4.3 (3=)	4.6 (4=)	1.55	0.0606	No
<b>Technical skills</b>					
11. Stability, strength, serviceability.	4.5 (2)	5.0 (1=)	2.14	0.0162	Yes
12. Loads.	4.3 (4)	5.0 (1=)	2.69	0.0036	Yes
13. Economy.	4.6 (1)	4.4 (9=)	-0.21	0.4168	No
14. Materials knowledge.	4.2 (5=)	4.8 (4=)	2.41	0.0080	Yes
15. Load paths.	4.4 (3)	4.6 (6=)	1.12	0.1314	No
16. Visualise failures.	4.1 (7=)	5.0 (1=)	3.19	0.0007	Yes
17. Analysis, design and construction.	4.2 (5=)	4.6 (6=)	1.69	0.0455	Yes
18. Standards.	4.1 (7=)	4.4 (9=)	1.25	0.1056	No
19. Computer and design aids.	4.1 (7=)	3.9 (11)	-0.49	0.3121	No
20. Short-cut methods.	3.7 (11)	4.6 (6=)	2.55	0.0055	Yes
21. Drawings.	4.1 (7=)	4.8 (4=)	2.44	0.0073	Yes

**Appendix D4 - Building for People N - Overall Assessment 2001**

<b>Student</b>	<b>Steel pro</b>	<b>Conc Pro</b>	<b>Prac</b>	<b>Steel exam</b>	<b>Conc exam</b>	<b>Total</b>
	<b>20</b>	<b>20</b>	<b>10</b>	<b>20</b>	<b>30</b>	<b>100</b>
HB	16.2	17	6.5	8.5	13.5	62
EB	16.2	17	6.5	5.5	15	60
SD	18.3	17.9	7	2.3	16.3	62
FL	16.8	13.3	5.5	5.8	5.3	47
SK	18.3	18	9.5	19.8	25.7	91
CK	13.1	13	7	12	13.8	59
GL	18.3	17.9	6	18	22	82
FL	17.8	19.1	7.5	16.3	8.2	69
WL	17.6	17.1	8.5	10.3	16	70
BM1	15.5	8.5	6.5	2	12.5	45
NM	17.2	14.7	5.5	6	13	56
BM2	17.7	17.6	6.5	14.7	16.3	73
LP	18.1	17.6	9	15.5	17	77
WP	18.3	18	9.5	8.3	16.5	71
JP	17.8	19.1	6.5	11.3	14.5	69
PR	13.1	13	5.5	7.3	12	51
AR	17.2	14.7	6.5	14	19.5	72
NS	18.1	16.5	0	10	17.5	62
MT	15.5	12.9	0	5.3	16.2	50
YW	13.9	16.5	5	9	22.3	67
<b>Average</b>	<b>16.8</b>	<b>16.0</b>	<b>6.2</b>	<b>10.1</b>	<b>15.7</b>	<b>64.7</b>





Skill no.	Assessment method	Poss marks (of 100)	HB	EB	SD	LE	SK	CK	GL	FL	WL	BM1	NM	BM2	LP	WP	JP	PR	AR	NS	MT	YW	Ave	
	Analysis																							
T17(a)	Part Q 2(a),(b), 3(a),(e)	10.5	29	33	33	14	86	26	50	50	19	7.1	17	41	48	26	57	21	74	45	50	57	39.2	
		% of attempt	46	64	70	23	86	42	81	81	40	12	35	65	77	42	92	35	74	73	50	57	57.2	
T17(b)	refer mark sheet	1.2	100	100	92	100	100	83	92	100	75	38	67	83	83	100	100	83	67	75	50	75	83.1	
	Design																							
T17(c)	Part all except 3(a),(e)	37	45	41	35	23	92	56	87	47	59	32	41	67	68	55	48	41	63	56	41	62	52.8	
		% of attempt	45	41	49	27	92	56	87	72	65	32	46	67	68	55	53	41	63	56	41	62	55.8	
T17(d)	refer mark sheet	19.8	81	81	91	76	92	65	91	91	81	62	84	81	86	92	91	65	84	88	78	82	82.1	
T17(e)	Not assessed																							
T18	Overall projects	40	83	83	91	75	91	65	91	92	87	60	80	88	89	91	92	65	80	87	71	76	81.8	
T19	Not specifically assessed																							
T20	Not in course																							
T21	Project draw'gs & pres	9	79	79	99	62	88	58	99	93	91	64	73	93	89	88	93	58	73	84	61	69	79.7	

## **Appendix E**

Appendix E1: Focus sheet for student interviews

Appendix E2: Information from five individual students

Appendix E3: Interview transcript with SK – 25 July 2001

Appendix E4: Interview transcript with GL – 26 July 2001

Appendix E5: Interview transcript with JP and FL – 31 July 2001

## **Appendix E1 - Focus Sheet for Interviews**

### **Critical concepts in the course?**

- Understanding loads and how to model them
- Understanding strength, stability and serviceability
- Design in steel and concrete
- Functional, economics, constructability
- Professional presentation
- Australian standards

### **Teaching and Learning**

What aspects/methods used in the course gave you opportunities for ***meaningful learning***, i.e. learning which involves understanding and can be used to solve problems in new settings.

Teaching and learning opportunities included:

- Formal lectures
- Tutorial exercises
- Design projects
- Laboratory exercises
- Text books
- Feed-back on projects, labs
- Group discussions (2 or more people)
- Asking questions of lecturer outside class time
- Informal chatting with lecturer
- Informal chatting with other students
- Exam revision

**Opinion on design projects as a learning tool vs other methods (lectures/tutes etc.)**

## **Pros and cons of projects**

- Understanding
- Time
- Working in pairs/alone

**Do you think you could learn using projects alone?**

**Do you think projects are only suited to Structural subjects, to all subjects , to no subjects?**

## Appendix E2 – Five Individual Students

Observations from videotapes, researcher's journal and student's journal for each student in chronological order

### SK

Videotape general observations: SK always sat somewhere near the front during project sessions, participated actively in discussions and usually had specific questions to ask of JM in consultation times. As the top student in the class, other students also often consulted him during class time with questions. His partner in both projects was W P but WL (partnered by LE in first project and on his own in second project) also worked with S K. and WP frequently in class.

Journal: Generally SK used his journal to record technical questions he wanted to clarify with JM at the next project session and included lots of sketches of areas he was thinking about, then recorded the answers to his queries in the journal later. This was particularly so for the second project.

Journal Week 1 "Problem understanding code w.r.t. side wall, upwind and downwind external pressure coefficients. The code specifies: 'horizontal distance from windward edge' but where to?"

5 March

Video: At class, working with his partner WP. At 35 mins BM1 then MT go to SK to ask questions, then return to seats a couple of minutes later when JM goes through something on the board. JM talks to SK and WP from 46:01 to 48:15. SK remains working until tape finishes.

Journal Week 2: Queries re area (for racking force) – try to clarify with Julie before the weekend so I can progress through.

12 March

Video: SK sits next to WP and WL turns to talk/work with them during the session. JM consults with WP & SK from 16:10 to 16:50. During the interactive lecture from 37:00 to 56:00, responses to JM's questions or questions asked of JM come from SK (2), WP (3), LP (2), NS (3). From 59:35 SK, WP and WL are "off-task" talking about something else. At 1:01:10 JM goes to talk to SK and WL (WP leaves), and continues until the end of the tape at 1:05.

Journal Week 3: "I understand the bracing system needed for both sides of structure ... However I am a little unsure in translating this to each (main) bracing system. Must ask JM and consult with WP to see what ideas he has."

19 March

Video: From 6:00 JM gives interactive lecture until 38:00. During this time several questions are posed by JM. Responses are generally from WL, SK and NS. SK is attentive throughout the lecture. After that, several students leave due to a "Rocks" test in the next hour. SK, WL, WP and LE stay to discuss some things on the project then leave by 42:00.

Journal Week 4: After lecture, I began rafter design starting with load combinations. I believe the process I followed was correct. However I am a little concerned with introducing wind loads into the load combos. I have attempted to include them but before I go further I would like to confirm my methodology. Once this is done the rest of the member design will be fine. I am competent with the section and member moment capacity.

26 March

Video: SK is present and working. JM consults with SK and WP from 7:30 until 18:40. They continue working and talking with WL/LE about loads. From 34:50 to the end of the tape, JM is giving an informal lecture to the group that missed the session the previous week. During this time SK continues working with WP quietly. WP leaves at 53:30. WL goes to SK with a question at 57:00 then again at 1:04:00 until the end of the tape.

Researcher's journal: WP & SK are progressing very well as expected. Questions are always to ensure they have understood the concepts, not "How do we do this?" Both have good conceptual understanding. WP's baby due next week, but they are well on time.

Journal: Consulted with WP, we have been both doing the calcs. To become more proficient at them and our designs have been in agreement.

3 April

Video: Class opened with a discussion session from 1:30 to 39:50. Questions were answered or asked by SK (4), WL (2), LP (6), NS (4), JP (1), FL (1). At 44:10 SK goes to look at the drawings JM has brought for class to look at. WL talks to SK from 45:30. By 47:30 SK, WP and WL are talking fishing "off-task". At 57:17 JK goes to ask SK/ WL a question, at 59:20 NM asks SK, WP and WL about fly bracing. At 1:01:40, WP and WL leave, NM thanks SK for help and SK leaves by 1:02:00.

Researcher's journal 4 April: Questions from WL & SK re combined actions. WL has been working with SK, not sure how much LE is doing at all. WP and wife had baby boy last Friday morning, they may need an extension of time but are going to try to meet deadline. Questions relating to understanding concepts of combined actions.

Journal Week 7 "We have not gone through much theory as of yet to initiate the project to any degree. Spend time understanding what is expected in the project."

7 May

Researcher's journal: SK came to see me with some questions first thing in the morning. He has done the reading and RCAus as well as attempted all of slab panel A. Said he felt that RCAus was a good complimentary learning tool to the test and that my notes summarised things well. Also said that the project was "where things come together for him" and was "very important". His queries related to slab depth using Warner and how to interpret  $\text{mm}^2/\text{m}$ .

Video: At 1:10 SK and WL in discussion. At 9:45 SK, WP and WL are chatting off-task, still at 12:40 and getting louder, still at 18:35. SK says (referring to camera) "That's not on is it, it's not recording is it?" At 20:40 SK, WP and WL start work, discussing reinforcement tables. By 23:00 off-task again, waiting to ask their questions to JM (although they were discussing their experiences with mixing and pouring concrete). At 30:00 still off-task, only other students remaining are the 4 in discussion with JM as well as GL and SD. At 31:55 SK asks question to JM re slabs, discussion is joined by WP and WL and continues to 41:50. From 42:50 to 46:50 JM chats with WP and SK about WP's new baby then SK and WP leave.

14 May

Video: Tape opens with JM answering questions from SK/WL until 1:50. SK then continues working with WP and WL but off-task at 24:50, packs up at 28:30. SK checks with JM that she is not going through anything with class, just consulting, then leaves at 30:00.

Researcher's journal: SK came to ask a couple of questions earlier in the morning – did not stay long at session. They are well into beam design.

Researcher's journal 22 May: No designated project class this week due to public holiday on Monday. SK asked about loads to CB2 in lecture break today so I went through that briefly with class.

Researcher's journal 24 May: Questions from some students today. SK was clarifying the use of 3-moment equation including positive moment calculation. Also checking Column C1, first trial indicated neutral axis is above compressive steel, wanted to check that this was OK.

28 May

Video: As tape opens WP, CK and SK are talking football, start work at 1:07:00 (this tape commenced at 1:05:00, second session on same videotape). At 1:20:40 WL/SK go to look at example drawings JM has brought. JM answers their questions from 1:23:20 to 1:26:50. They then continue working until 1:45:20 when they pack and go (second last to leave).

5 June

SK did not attend this session as he had already completed his project.

## GL

General observations: GL is a mature age student who completed a Diploma in Civil Engineering over 10 years ago and has since worked in the civil design area as a design draftsman in the civil works field (road, drainage, sewer design etc.) He works full-time at a local council in the engineering department and is now completing his degree part-time. He is granted study leave from work and makes up other hours, but is only able to attend campus on 1.5 days per week.

Video: As the project session was on a different day to the lectures, JM agreed that GL did not have to attend the sessions, his partner S D. would attend and GL would consult with him. In addition GL emailed or rang with questions and attended JM's office with questions on days when he was on campus. GL is a very hard-working and conscientious student.

Journal: GL generally used his journal as a diary and time record of work on the project.

*5, 12, 19, 26 March*

Video: Not present due to work commitments

Researcher's journal 13 March: Consultation with SD & GL for about 45 minutes (GL can't attend Monday sessions due to work commitments, he is a p/t student with f/t work). They are a bit behind due to delay in getting HB 2.2 but seem to have wind loads worked out OK. Some confusion over wording – it really is a poorly written code (AS 1170.2).

Journal: 20/3 "We are one week behind the schedule. We both agreed that the project appears to be providing difficulties because we have had no previous exposure to this type of work and therefore we are unsure as to how we set out the structural calculations. It would be useful to have an example to follow."

Journal 25/3 "Meeting with a structural engineer to seek advice and information and reference books"

Journal 27/3 "Meeting with JM to confirm various aspects. Calculation of wind loads. Confirm design meeting at 19:00 at City West with SD to continue with project.

Journal 29/3 "Reading books/notes to determine design procedure and method of setting out calculations."

*3 April*

Video: GL does not participate verbally in the informal lecture, but listens attentively. JM consults with GL and SD from 59:20 to 1:02:26 and they remain working when tape ends.

Journal 8/4: "Met SD at City East library. Design of Column C2 was carried out. Some design complications due to lack of understanding or information were discussed and partly resolved. SD carried out design of column C1. Design of C1 was found to be very confusing and not much design progress was achieved. SD will see JM at UniSA on Monday to discuss design of C1. Decided that next design meeting at 19:00 at City East Campus will be necessary to carry out and complete connection design.

Researcher's journal: Marking observations project 1 – Excellent drawing (of course, with GL's drafting background), very well presented and very good technically. Misconceptions were effective length for ridge beam. Few minor omissions/mistakes – overall excellent.

*7 May*

Video: JM talks to GL and SD to 12:40. GL and SD stay for the full session working quietly together. At 50:46 GL asks JM a question and discussion follows for a couple of minutes. Still working quietly when tape ends.

*14, 28 May, 5 June*

Video: Not present due to work commitments.

Journal: Project 2 17/5 "Meet project partner at UniSA City East Campus and work through completion of Slab Panel A and design most of Slab panel B. Confusion over the requirements for crack control have been raised by both and clarification will be sought from JM. Design work at this stage is proceeding well and on time with the recommended time schedule."

Researcher's journal 29 May: Questions after lecture from SD & GL, Is 130 slab too thin? Agreed it probably is but they should go on with it now and just make a note in the calculations that they should have used thicker.

Journal 1 June: Called [JM] today and clarified the design issues in relation to CB1. Continue with design for bending. However, make adjustments to design for bending as a result of previous errors made calculating loads and bending moments.

Journal 4 June: Short design session. Clarified some minor steel detailing issues with [JM]. I prepared a schedule of tasks required to complete the project with [SD]. It will be necessary to meet at City East Campus at 19:00 on 6 and 7 June to complete the design work.

**JP**

General observations: JP completed a Diploma in Civil Engineering in the Northern Territory and has worked for a couple of years in the Department of Roads in NT as a soils technician. He came to UniSA in 2000 and has been given credit for much of the first two years, but has been undertaking Maths courses from first and second year with the later



engineering courses. A clash between group meetings in a Maths course and the project sessions for this course prevented his attendance at some sessions.

Journal: JP also used his journal as a record of progress along with questions and answers. Whilst he expressed concern at their progress and understanding during the first project, he was much more confident with the second project. This probably related primarily to the pressures of a mathematics course he was taking simultaneously, which had some project deadlines during the first project.

### *5 March*

Video: JP arrives a few minutes late then moves seats a few minutes later to be able to share looking at a copy of the Australian Standard with another student. After the class starts working in their groups JK comes to work with JP at 17:20. JP continues working with FL/SD and JK during the session. JM consults with JP/FL from 48:15 to 51:47. JP remains working in class until the tape finishes.

### *12, 19, 26 March*

Video: Not present due to clash with Maths group meeting.

Journal: 26/3 "We are in trouble. We have way too much to catch up with the project. I have a huge Matlab assignment and so does FL so we have to make time ... I think I am lost. I have to talk to FL."

### *3 April*

Video: Participated in class discussion (see SK notes). At 40:14 FL and JP go to look at drawings. At 41:30 JP is still looking and making notes until 42:36. At 46:55 JK is talking to LP and JP. JP works with LP for the rest of the class.

Journal: 9/4 "We need to see JM or anyone who can help us with bracing. We have spent a whole weekend working out the bracing. Me and FL working on bracing separately, we get different answers."

Researcher's journal 9 April: FL & JP were still stuck on bracing. JP seemed to understand it but FL wouldn't let it go. Eventually advised him to move on as he was spending too much time thinking about it and confusing himself. They are concerned they won't finish (I agree) and asked for extension, but not granting one since they have no excuse other than too much work in other subjects.

Journal: 12/4 "After being awake for 26 hours it has come to an end."

Researcher's journal: Marking observations project 1 – Good effort at end since they were way behind. Misconceptions were bracing compression taken by rafter, omitted  $\phi M_b$  check for uplift on rafter,  $\beta_m$  column wind load bending moments mixed up cases. Only pair who even attempted the 0.9 and 0.5 wind load case on rafter and did it properly too.

Journal: Project 2 24/4 "JM handed out the project. I think it seems interesting. This set of drawings are hard to understand."

Journal 1 May: We can now design Slab A. Maybe the weekend will be a good idea. I have been through the project but drawings still hard to follow.

### *7 May*

Video: JP arrives at 2:00, leaves the room briefly from 10:00 to 11:30 then leaves class at 12:40 without talking to JM.

*14, 28 May*

Video: Not present

*5 June*

Video: Present but session not taped.

Journal: 6/6 "JM had answered my question so I was able to finish CB1. Shear design was good. Spacing of bars was very easy. Shear capacity good."

Journal 8 June: Started on C1. I had a few problems with it, especially with  $k_{ud}$  when working out  $M_{uo}$ . I had to ask questions and [JM] was really helpful. [LP] was helpful with some advice.

Journal 12/6 "Finally, I'd like to say that this project was pretty good. I am very confident that this project will help me with my exam and for future projects."

## **FL**

General observations: FL's background is very similar to JP's except that he completed his Diploma at the University of South Australia and is of Italian background instead of Greek. FL was undertaking the same Maths course as JP and hence was also unable to attend several of the project classes.

Journal: FL did not submit a journal for the first project, and only started one late into the second project, but did reflect on his progress.

*5 March*

Video: Same as JP (they were sitting nearby)

*12, 19 March*

Video: Not present due to clash with Maths group meeting.

*26 March*

Video: Present at start of session. Leaves room from 2:55 to 8:50 then returns and works on his own. At 15:45 FL packs stuff and leaves.

*3 April*

Video: Participated in class discussion (see SK notes). At 40:14 FL and JP go to look at drawings, FL looks briefly then returns to them at 44:10. At 46:55 FL leaves class with bag.

*7 May*

Video: At 3:00 FL moves seats to work with BM2 and LP. At 15:57 FL leaves class without talking to JM.

*14 May*

Video: FL stays in class while JM makes some announcements etc. but leaves at 15:20 without talking to JM.

Researcher's journal: JP not present. FL left before I got to him but asked no questions when available earlier. Presume they haven't started.

*5 June*

Video: Present but session not taped.

Journal: 5/6 "Have been working on CB2, has been frustrating at times. Just when you think you know what's happening something changes all your workings... Almost forgot to take into consideration the roof loads, all under control now!"

Researcher's journal 7 June: Questions on and off all day – especially FL (driving me crazy!). Some are basically just checking they are on track and that their method is correct.

Journal: 8/6 "Project is huge, there is a lot of pages, a lot of work has gone into this design, would it be the same in a consulting office?"

## NM

NM M is a student who commenced his degree after completing Year 12 at high school. Although he got very good Year 12 marks, and is considered by staff to be bright, he does not attend classes regularly and does not appear to do a lot of work (other students advise that he works considerable hours in part-time employment). He generally passes classes but does not achieve to his potential. Seems to be liked by classmates but is not generally well regarded by staff due to his perceived "slack" attitude to attendance and required work. NM completed the projects with AR who is one of the brighter students in the class.

Video general observations: During project sessions, NM was often working on other coursework, or socialising in the adjacent student workroom. Many of his reported absences during sessions were to go next door to this room. When present NM usually sat at the back of the room and was often off-task talking to other students.

Journal: NM completed a journal for the first project but not the second. However his partner's journal can be used to gain some insight into what NM was doing.

### *5 March*

Video: NM is at class. Leaves the room after 25 minutes, returns 6 minutes later, leaves again, returns again 8 minute later. JM talks with AR/NM at 55:15 for about 1 minute – presumably they had not started the project as yet. He remains in class until the tape finishes.

Journal 6 March: AR and I worked on windloads. Not too sure how to set these out. We have lots of pieces of paper, it really looks too large for a small section of the report. We both kinda agreed to look it over and try to figure it out.

### *12 March*

Video: JM consults with NM/AR from 4:30 to 7:00. At 11:00 NM leaves the room, returns at 19:00, leaves again at 33:50, returns at 36:50, leaves again at 59:00, returns at 1:04:10 and leaves for good. He is basically not working on the project, keeps going next door to work with other students on something else.

Journal 13 March: Wind loads were OK. We did have too much done. I told [AR] I would do the bracing. I think I know what to do. [AR] said he would try the rafters.

Journal 15 March: Tried bracing doing tension and compression members. Looks OK and seems reasonable. Had a quick look at how we would start combining the report. Decided to do it on computer. Will talk to Andrew about it later.

### *19 March*

Video: Not at class but in adjacent student workroom. At 6:00 JM goes there to get him and another student to listen to the rafter design discussion so that she won't have to repeat it

again to them. Informal lecture continues to 38:30. At 29:40 NM is off-task talking to BM1, then continues off-task talking to CK. At 32:50 leaves the room although the lecture is continuing.

Journal 22 March: Talked to [AR] about him going on hols. I said I would keep going with it and when he came back he said he would take over and check them.

Journal 25 March: Did a long session today, had a look at rafters, ridge beam (? Still unsure), column 1, column 2 will wait until column 1 finished. I am pretty happy with it but am a little unsure. Worked with [BM1] and [MT] today and threw ideas around. Overall a very productive day!

*26 March*

Video: Not present

Journal 1 April: Talked to [BM1] again and found a lot of mistakes. Re-checked them all and left it there for the day.

*3 April*

Video: NM enters the class at 55:20, goes to ask SK, WL and WP about flybracing. At 1:01:40 NM thanks SK for help and leaves.

Journal 5 April: Talked to [AR] and showed him what I did, he was pretty happy and we arranged to meet Monday and do a full day on it. Decided to take weekend off.

Journal 11 April: Did a couple of hours formatting, fixing drawings and adding clauses etc. We then bound it and handed it up about 1:00 a whole day early. Whoo hooo!!!

Researcher's journal: Marking observations project 1 – Misconceptions were bracing member directions confused,  $\beta_m$  values,  $I_c = 4000$  for C1 buckling x-axis, loads to Col C2 very confused. Errors – minor.

*7, 14 May*

Video: Not present

From [AR] journal 25 May: NM and I met today and we are further than I had suspected. [NM] said that he had started the columns and they were coming along nicely. What (I think) we have decided to do is that I will finish the slabs and do the beams, he will do the beams and then he will do most of the write-up as I did the majority of the calcs.

*28 May*

Video: NM is not in the video picture but is marked on attendance record as present. No record of his participation in class on tape, or of him arriving or leaving. Suspect the attendance record is incorrect, or that he left early before the tape began.

*5 June*

Video: Not present.

There is no further mention of NM in AR's journal until 4 June when the entry is "Sent file to [NM] so he could start write up". Then on 8 June "Talked to [NM] the other day and he said he had finished columns and has started writing up the project. As I thought CB2 came out very easily. I sent the finished file to [NM] and a note saying that we should get together on Monday (due Tuesday) and really finish it off. Over the weekend I am going to finish the drawings.

From [AR] journal 10 June: Rang up [NM] who said that he had nearly finished writing everything up and that we didn't have to meet tomorrow. I made sure that he had got my last email which he said he had and I told him I would do the drawings.

From [AR] journal 12 June: Met [NM] at 8.30 am but went in early and wrote up the 3 moment equation part for CB2 as [NM] won't understand what I did on the spreadsheet. Met at 8.30 am and after about half hour I realised that [NM] HAD NOT received my final completed file and so he did CB2 his way and I think also a bit of CB1. The answers were different to mine and he hadn't used the 3-moment equation bit it may still be alright as he used references. Anyway we fixed up a few things but didn't have enough time to go right through the whole thing. Fingers crossed its alright. Handed up at 3.00 pm.

### Appendix E3 - Interview with SK - 25<sup>th</sup> July 2001

JM Basically the interview is about Building for People and your experience in that.

In general with Building for People, what did you think were the critical concepts in the course?

SK In general - well there were lots of 2 components of steel and concrete and then I guess it was introductory, it sort of took, it was the practical follow on from Mechanics & Structures, where you learnt the basic theory of how to go about shear force, bending moment diagrams and understand the physical actions that this was taking, looking at the aspects of the two types of the main materials, steel and concrete, and analysing the different structures of those materials and so having a good understanding of how to analyse a steel structure and what is involved and likewise with concrete and doing reports.....?

JM What about things like loads and stuff like that?

SK How those structures are able to support loads and how you can analyse the maximum loads that those structures can handle and the different loads and things that you have to consider with those loads. For instance, steel being more uniform, the size of the member was more critical whereas in concrete we had the idea of reinforcement, so that was a different analysis completely compared with steel.

JM Any other kind of concept that you felt we were trying to get at in the course, so you told about the loads, structural analysis, steel & concrete materials, design etc

SK I guess and then within each of the materials we looked at components of structures, then connections, columns, beams, and then how each went along with materials and loads and then looked at more individual types of members. That came across fairly good and the progression that worked very well in both facets sort of worked from the simplest to the more difficult

JM The only other things that I was trying to get across was obviously the importance of say the Australian standards.

SK Oh of course, Yeh that was obvious.

JM And then other things about presenting the work knowing how to present calculations...some of the economics of design...

And with teaching and learning the way we taught that particular course. Which of the aspects of the course do you think were - gave you opportunities for meaningful learning, like learning that helped you to understand?

- SK It was actually quite good because that, the whole subject, it's going to sound a bit, I'm not trying to sound sucky, but it was geared the way I learn which was really good. We were presented with materials and then it builds you. This is the way I work even if its not around formal tutes and that in a course and then we are able to have practicals and/or the projects which just compound everything you have learnt, especially the projects that you used every bit of the theory that we were taught a week or two previously. That progression of having being taught some theory and then being able to apply it in a real manner, that's the way I learn. The combination of everything...
- JM So the mix of lectures and tuts and pracs and projects
- SK And I thought it was all slotted really sequentially very, very well. Because that's the way I learn anyway, getting the theory, reading about it and then trying to do problems, tutes and then practical and having a project sort of almost disassociate itself from the normal theoretical tutorial kind of problems. But it was all based on that so even though it appeared disassociated in a work sense, it was all the same work so that was good, and realising that, oh, it is just the same work that you were doing if someone gave you three questions to do for homework. One on connections one on strength and this was all brought together in the projects and that was like the icing on the cake.
- JM And what about working with others on the project and that kind of thing etc?
- SK Working with others is good. I actually had a better working relationship with other people outside of my group pair. So having or knowing someone we can rely on, whether it's your course lecturer or other people that are working with the same calibre as your group it's good. I always struggle with that, with group work, to find someone with the same calibre and not to blow my own trumpet, but it is difficult to find someone as enthusiastic. Certainly I struggled, unfortunately, with my group. But you have to do it and I have worked with other people on other things outside of the University you have to do it, but you find people of the same calibre out there, it is difficult at university
- JM What did you feel about the time required in this subject?
- SK It was all right, I don't think it was too extreme. I think it was reasonable, it was pretty much on par with work we had to do compared with other subjects but I don't think it was too much. It was demanding, but I don't think it was too much to ask especially at this stage of the game. It was pretty good. Keep the pressure up.
- JM When we came to the exam do you think the way that the subject had been taught associated in terms of the exam or did you feel the exam was not based on the right stuff?
- SK It was representative, I mean it was - because you could only examine so much and you expect more or expect other things to be in

the exam and I think there was a fair representation of all the work and so you are forced to study for all of it. I think it was all right. I reckon I worked for two and a half straight hours in the exam and then used the last to revise. It was a reasonable amount of work. That happens - it is a fair representation of what we did and it wasn't everything. There's quite a few things that might be in there that wasn't, but and for me having looked at the last two exams as well, I think it was a reasonable exam. It also depends how you do, I obviously did alright so it was OK.

JM What's your opinion about the Design Project, in particular as a learning tool compared with maybe other subjects? And also what you mentioned about the design project being tied in with the lectures?

SK I think they're good and like this project was probably good precursors of what we should be moving towards, especially in final year. So in that sense I think it is good and it's probably a nicer change from just having assignments. For instance, tuts in Soils and Rocks you get seven assignments, nothing that is really project orientated, whereas with the projects you have a bit more flexibility too than an assignment would. It's not so much right and wrong as far as experimenting and with design and being able to put a bit more thought into it - a bit more of your own ideas. It's not just a question with a right answer, its how you manipulated the problem and to come up with a reasonable answer, not necessarily the right or wrong one and I think that the steps involved in a project too is important. I'm quite sure thinking through steps somewhat appears to be the most, a huge task at the beginning and then how its broken up into the end product it's very beneficial

JM And do you think the handouts basically did that?

SK Yes

JM In terms of allocating the marks and all that, was that helpful?

SK Oh yes, it definitely was, yes it's good especially not having much experience at doing that and having it done and seeing what - how to maybe break something up in the future, it was very beneficial

JM And how did you feel about you know, were the projects kind of related to what you believe practice will be like, kind of thing?

SK Yes I don't think they were too superficial. And too, they can't be too ambitious, at this stage of the game they have to be fairly simple and I think they were reasonable. For instance the last one, a two storey house, that had all the plans, you feel like you're doing it for someone anyway, you had all the plans which - whether you used them or not probably used one or two of them, but to have the bunch of plans, sort through them to look at, it is something that is quite realistic. They didn't seem superficial or false, like we did one for water as well - hydrology, drainage project and too we had to go on site, it was all real, the roads were real and do the measurements and get the CAD plans, so really



gearing towards something that's substantial and ultimately realistic and something you could attach to a CV, be quite proud of it, that's what projects would produce.

- JM What other issues relating to the pros and cons of projects, some of which you talked about the pros, what do you think are the cons of the project?
- SK That's kind of an interesting question because I don't know if you could be an engineer if you thought there were too many cons about project work. I guess the biggest thing to grapple with a project, whether it is a con or a personal issue, is that it seems so big at the beginning and the project is, yeh we've got one now for Computer Applications for Engineers where they just seem very, I don't know, just out there and you've got to try and pull it all in and start it and sometimes it's not easy to start things. Sometimes you just sort of don't know in what direction to go because you either haven't had the lectures or you don't have the knowledge yet so you have to wait a few weeks, that kills me. So I think that's the biggest con I face with projects but I think projects are pretty good. The idea of something that's big and you have to break it into little pieces and do some research, find out information - they are good things, I don't know if you'd really be an engineer if you didn't like projects. Having said that too you probably wouldn't do it if you didn't like working in groups either or not being able to take a role. Some students, especially in a bigger group are very shy and very, I don't know, what it's be - how they think they're going to one day come out of that. It's something they really have to start doing from first year, especially when groups are bigger and you get quite a lot of group work throughout the whole degree, and I think yeh you have to be at least active in that to enjoy it but the cons, other than that I can't really see any negative aspects of the projects.
- JM And do you think it would be possible learn with the projects alone in an engineering course?
- SK I couldn't see that because, I mean, you need something you need some basis for us to go on with. I mean you need some body of knowledge to base your project on. Unless it's something that already you've picked up maybe throughout the course this is more like the final year kind of project that's a subject.
- JM Of course in our final year nearly half of it is projects
- SK Yes
- SK Unless as far as all the marks for the subject or the course being project. I don't see why not, there's been a lot of work put in to the projects. However, I mean they would have to be so much bigger too, just based on the same number of people - looking back at those they were 20% each.
- JM Yes

- SK They would have to be substantially bigger to be worth a bit more than the exam. I think the exam is pretty good too. It's probably pretty hard to base a whole subject or course on project work. I don't mind a bit more weighted maybe 30 each or 20 each. Just on that subject I thought the practicals were a little bit highly weighted.
- JM And do you think projects are only suited to structural subjects or more suitable or if they can be used...?
- SK No, not at all, I think they can be used everywhere, in all of engineering, that's what it is, that's what it's about, projects solving the problems. I guess what I'd like to see more of though is not just concentrated on structures, maybe to superficially create some kind of liaison with other groups or for instance environmental things we did a little bit of. Because that's where I think it's at as well - Civil and structural, bit of cross-pollinating, so to speak, get a bit of that going on, having to deal with other people.
- JM That's certainly our final year project where we do that.
- We did also used to have a combined Structures and Geotech project in Building for People for a couple of years.
- SK I could imagine it's pretty difficult to pin it down and to not make it either too easy or just really, really difficult. It has to be sort of within reach of our immature knowledge, but - I think it's worth exploring. We did just a tiny bit about for the hydrology project where Lindsay introduced a bit of an environmental angle to it - and I think it works well. At least get's us thinking about it.
- JM OK Thank you very much.

## Appendix E4 - Interview with GL - 26 July 2001

- JM With respect to the course what did you think were the critical concepts that we were trying to get across in that course?
- GL I feel it was getting the grasp on the practical side of things, on how to analyse complete structures, how practically we analyse a structure, work it out from beginning to end. Rather than have the loads given to us I felt that the main issue there was working it out, working the loads out ourselves. I found it to be very practical in that sense, so that's what I got out of the subject.
- JM Apart from loads what then was there likely to be in structure design the other concepts that we were trying to focus on?
- GL Using the code, moving away around the code and learning to understand the code, what the aims of the code are, understanding limit state design basically which is what the code is based on.
- JM What were the limit states that we are talking about here?
- GL Once again I should have looked at my notes before I came here I think.
- JM Alright, one of them in design is strength.
- GL Oh yes there is the strength, what was the other one, section capacity.
- JM If I go back with them OK - if I say we were - the projects that you were designing say the roof beams or something like that what were the kind of concepts that we looked at?
- GL I know what to do but putting it into words - I find difficult. Obviously we check the beams for shear, we check them for bending, obviously, and if they are subject to any axial loads, check them for compression or tension. Checking all these different aspects or loading conditions on the member and through the procedures, there are all these built in small little factors of safety which are all built into the procedure as you're going along and that's all spelt out in the code.
- JM The ones I had down were the loads and limit states which is strength that you talked about and the others we talked about was serviceability.
- GL That's right Yes it's come back to me now.
- JM What about the material side of things, basically we covered the two main construction materials.
- GL Steel and the concrete.
- JM Ok the only other things I mentioned was presentation of calculations of things and drawings, which of course you will recognise from your work experience, so for you that probably wasn't a concept that you needed to learn in the course because you already knew it.

- GL Yes Although I've got more experience from doing that from a drainage point of view, I've now got a bit of experience of doing it from a structural point of view. Draining is a little bit different but the same concepts were there.
- JM With the teaching and learning, the ways we taught the course and the ways you learnt in the course, what were the methods or whatever that you thought were the best for you in terms of meaningful learning or getting the most out of the learning?
- GL Firstly, tutorials are really good because you learn all the theory that you pick up in class, what goes on, what's taught in class, you get a little bit of practice at it,. So that's really good and of course at the end of the year you can go through all of those for practice to restrengthen the methods used. And secondly doing the project, I found, strengthened that even further because then you can see how all these little bits that you do in tutorials fit in one complete structure, which is what we do in the industrial shed. So the project was good from a real practical point of view and it was interesting because you could see how it was all coming together and it tended to follow pretty much what we learned every week in the lectures. So that was that point of view.
- JM What about the things like the pracs in the laboratories and whatever?
- GL The pracs were good because that helped you to understand how the materials behaved, limits of the materials. Helped to strengthen more a little bit more the theory although there was one point where it was difficult to pick up. I found it difficult to understand the pracs because the timing wasn't quite right, one of the pracs we did before the lectures and I went to a prac and I didn't completely understand what was going on but then later on down the track a few weeks later, as things got together, I did pick it up at that point and then I thought to myself, 'ah so that's what that prac was all about' but at the time it was hard to understand what was going on.
- JM I was a little bit annoyed that that prac got moved because it was meant to be the week after.
- GL It would have made all the difference the week after and because of that doing that assignment for that prac I actually didn't do too well because I didn't understand entirely what I was doing and what the aim of the prac was. I think when students do pracs I think it's very important to really drum out what the aim of the prac is. Sometimes I walked into a prac and I tend to be a bit slow at picking up compared with other students and I tend to be a bit slow of picking up what the aim of a prac is what we are setting out to do, what are we going to learn out of this. So if the lecturer tends to focus on that a little bit more, then most of us might get a better understanding of what is meant to happen. That's what I find in my experience.
- JM What about the interactions in the subject, so you working with a partner, you working with other people in the class, interactions with the lecturers?
- GL That's always pretty useful because you get to share knowledge. You get other peoples perspectives on various topics and including the lecturer as well. If you're not clear the lecturer always explains things a little bit better in person, face to face, rather than in class. In class you tend to get more of an overview but if you've a more specific issue you see the lecturer you get more down to the

finer detail. With other students we're all in the same situation and some people pick up certain bits better than others and when you just talk about things with other people you get more of an idea of what's actually happening or what the outcome is supposed to be. Sometimes I pick up some things and sometimes somebody else picks up some things and interact a little bit or if you're working in pairs its always that little bit easier because you're combining information together.

JM And what's your opinion on the design project as a learning tool versus other methods like just purely say lectures and tuts or something?

GL Yes, like I said previously, I think the projects are really good because it helps to strengthen what you learnt from tutorials and what you learnt in classes even further. And it's a lot more interesting because you have got something practical in front of you that you're dealing with and you've got to visualise a little bit more as to what, how this things actually put together and how it actually works. Whereas in tutorials or in lectures you tend to only be given the beam and sometimes you don't know how this beam fits or where it fits into an overall structure. So when you've got, when you're dealing with a project, it tends to be something that's more complete, like the shed that we did. You can see all the elements fit in, you can see how they all interact with each other, how the loads are transferred through the system. That's the most important bit, you can see how the loads are transferred through the system whereas you don't really get that in a tutorial or in a lecture situation, so I think that project work is pretty important.

JM So you've talked a fair bit about the good points about a project, were there any bad points about the project?

GL I don't think that there was anything bad but at times it was a little bit hard because we are learning all new concepts and it's hard from that point of view because it's all new, and it's hard to just - the hard part is to get started, once you sort of get rolling it's OK. But umm I don't think there was anything bad about the project or negative because you gave us a procedure week by week, what you recommended we should do at certain stages, which was really helpful, because if we didn't have that you would have been bombarded with heaps of questions. So that was really important, no it was just that little bit hard and that was only because it was new.

JM It was challenging?

GL Yes, it was challenging

JM It was more difficult?

GL Yes, it was difficult at times, but I mean I found that if you did it in manageable bits and not fall behind so that you didn't work under pressure, then it was OK. But if you did fall behind and had to work under pressure, then I'd imagine that it would be really hard, so I kept on top of it, the schedule. Then it's OK and you apply what you learnt every week so it's fresh in your mind, then that strengthens what you learnt that week and also stops the panic rush at the end. So, no, I can't think of anything really negative.

JM What about the time aspect, was it too much work or was it alright?

- GL At times it was like a lot of work but looking back on it now that I've completed the whole thing it probably wasn't a lot, but at the time it seems a lot because it's all new and we have to do some self learning. I felt during the course of the project, so, because of the self learning component and trying to think about how to do things it takes a little bit longer so that puts the pressure on a little bit. At times I felt it was a lot but I think that's only because you saying that I was under pressure sometimes.
- JM Did you feel that it helped in terms of when you came to revise for exams?
- GL Yes, most definitely, because when I was practicing the problems for the exam I looked back on the project, I had a photocopy in front of me and I looked back and that's how I did that, so once again that was just another form, something else to look at to gain extra practice for exam study.
- JM Do you think that it would be possible to learn just using projects?
- GL No I think you really need tuts. You need to get concepts from a lecturer and you need to get all the theory behind it. The project on its own would probably be pretty difficult because if - people might find it daunting. I know I would if I saw the complete structure and I'd just had to learn based from that. I think it looks pretty daunting cause it's quite big, whereas in a class in a lecture situation you are learning how to design a column one week, you're learning how to design a beam next week etc etc and you're breaking it all down. So and you get that out of lectures and tutorials, so I think the project really strengthens what you learn in your tutorials and your lectures because it puts everything together and you've got a complete project. And also I think it's more interesting too because you have got something in front of you rather than bits of pieces, like what you get out of a lectures and the tuts.
- JM Do you think projects are only suited to structures or do you think they could be used in all subjects?
- GL I think all subjects definitely. One thing that I find very positive about this University is that it is very practical and if you apply projects in all subjects, when people go out in the real world, so to speak, they have got a better knowledge because they have already dealt with projects which are real life situations. So I think projects definitely apply to all subjects whether its drainage, structural or any other sort of engineering area, soils, anything.
- JM Thank you

## Appendix E5 - Interview with JP and FL, 31 July 2001

- JM Building for People, last semester. What did you think were the critical concepts that we were trying to get across in that course?
- FL Critical concepts - understanding the codes or working with the codes with timber and the steel areas,
- JP Reinforced concrete
- FL Reinforced concrete and steel. What else?
- JP. Well I think you people sort of show us how to design, get the fact across is the best design. Not the most economic way of going about it but the facts of the design, using the code and standard procedures. That's what came across to us like that's what you guys are trying to teach us was like how to use the codes, design a basic structure of a concrete or steel in both cases and I think that was done really well. Like when we use the other codes, the AISC codes, we realised this we could do it more quicker and more efficient, but that's what I probably
- FL That was unavailable to us, AISC, was it?
- JM You mean in a design capacity? Yes, I'll probably bring that in next semester.
- FL But, that was actually a bit hard to find. Sometimes I found those numbers and I couldn't work out how it was working. That was in [MPR's] notes I noticed that was. Yeh, I think just becoming familiar with the standards and the codes,
- JP Procedures and standard design.
- JM So in that standard design procedure what about the concepts that you needed, like to be able to design something, what were some of the concepts you needed apart from what the codes and standards?
- FL What - I'm not sure what you mean by concepts.
- JP The way I understood it was you need to know how your structure behaves, your end point connections, your segment lengths, and all that, you need to know stuff from your previous classes like Mechanics & Structures sort of background and mainly that class. Because that sort of class is all I done in this University, but you need to know your, how your material behaves and how it reacts, especially when we done the column and beam practicals we had to have that knowledge of how the concrete itself, it's ductile, it creeps and all that, how it reacts. I found the steel part, a bit more hard to understand, in the way where we cut off the segments, the spans of the length, the end connection points and I found some of the columns and footings, connections sort of different to what I had used in the project. So when the column goes into a footing I find that our specs were in the project, we used it was a pin or something, so the effective length didn't change. I think that's why we are doing it
- JM The only other kind of thing I was looking for really is loads

- FL Wind loads and things like that, Yeh that's pretty interesting learning about that. We hadn't done that anywhere else before and so I think [JP] and I actually we got stuck on that at the very beginning. Like at the beginning of the project we weren't sure how to tackle it, wind loads and the bracing and stuff like that, because that was all new. Like you say in Mechanics & Structures, we used the shear force diagram, bending moment, deflection and all that sort of stuff. But when actually applying it to a project, at first we were a little unsure, but once we got moving it was OK.
- JP I still think for myself that I'm not really - like in the design projects you let us get away with a lot of things or like you said, just take it slow or take that where if we had to work out other things like the load on the purlins that act on the steel battens, and the colorbond sheetings and all that, that would have been a bit more hard for us, not hard, because, like, uniform or point loads depends on what your member is designed for.
- FL You can't do all that you don't have enough time.
- JP I think it would have been a lot harder for us to work it out because we are not on familiar ground.
- JM We are going to do that this year, so the idea is try and stage it by the end you will have it all.
- In the way that that particular subject was taught, how or what do you think were the methods or whatever that gave you the chance to learn the best, like meaningful learning, learning that actually meant you understood?
- FL The way that you taught us was pretty effective. Each week or each two weeks or whatever it was, we had to get to a certain point with the project and sort of you were lecturing us on the material that we were meant to be keeping up with sort of thing, so you were effectively teaching us what we were meant to be doing and applying it to the project. And there was only - sort of - you'd only understand it if you went away and worked on the project and you'd get stuck and come and see you, or something. There were a lot of areas that you could make different mistakes in so it's pretty tricky in that sense. But the way we did it was quite alright, with lectures and then work away at your own pace and try and keep up. I mean I don't know how else you could do - teach that I mean.
- JP I really like that stuff, I really like the way you give us the notes, like every topic for every part of it, you could break a topic into other parts, you had an example for each other part and that's what helped me sort of follow through. I mean it wasn't the way we did it in the project but that was a starting point and for every part in the project that we wanted to design something, especially the concrete part, I used to look at your examples you gave us in class and I looked at the Warner book, other examples and just sort of followed the examples and standards and sort of go on.
- FL Some of the tutorials helped as well, like [MPR's] tutorials and yours, like go away and do the questions, understand the questions, then read some in between the materials and then try to apply it to the project. Not just try and do it straight out in the project.



- JP Especially when during class tutorials like after the lecture and tutorials, I found that the best. Like no way I'll go home and sit down and do a tutorial obviously you now know what to do but when I'm in class I'll actually sit down and did it and then I'd understand.
- JM So from what you're saying it sounds like it was like the whole thing, you know the lectures, the tutorials helped with the project, so you will say then ...
- JP I was more happy with your part in terms of understanding it better the way you - the tutorials were run and the way you gave more worked examples as we went through compared to [MPR's] section. He did it a bit different. I understood you better because I found your way more helpful but like I liked it because it was a step procedure.
- FL It's pretty hard material like to start understanding and all that stuff. I mean you sort of, you could use the code and tables and just the methods of calculating for steel and the concrete bits was, I don't know, just a lot of work, so took up a lot of time
- JM Do you think if the subject had been taught without the projects you'd still have that understanding?
- FL No the projects are much better.
- JP No way, the project is what puts everything together. It's your general knowledge and what you learn in class. Most of those projects is general knowledge
- FL By the end of that project like if you didn't understand bits and pieces of what was going on during the classes, then by the end of the project you just knew, like you could understand, how things fell into place and how to work things out. I think.
- JP But everything we did in the projects was covered in your lectures, apart from the concrete path everything else you were very familiar with
- FL It may not have been exactly the same.
- JP But we worked all semester on it so we knew it, so it was fresh still in our heads, I mean even now you could get me to do a similar project and I'd have no problem with it, especially with the concrete and steel I'd probably will
- JM So you're saying you think you retained the knowledge better than when you just study for exams.
- JP Yes, definitely because it's a long term process, whereas when you study for an exam you sort of cram two weeks and you've got other classes you study for, so you spend like five days on it than you do in the exam, and it's gone, finished - whereas for the project you spend ten weeks on it or 8 weeks on it and you work enormous hours on it, like coming in and checking on it so you know what you're doing. Maybe your work may not be 100% correct but you've got a general picture of the procedure. So I mean, I can't even remember what's in

the exam, and what questions you gave but if you ask me what the project steps were, I'd tell you step by step.

JM And do you think working in pairs was good or bad?

FL Yeh it was good.

JP Good because there's only so much one person can do like when you've got classes and you've got people overload and in one of those classes I already have - with Maths I found it took a lot of time so it was good to have someone doing parts of the other work. We always double checked each others work, most of the time anyway. Apart from that time when we ran out of time and said to each other, if you're happy, I'm happy. Like it's good because you can see where the other person has gone wrong and the other person can see where you have gone wrong and you share your ideas at the moment - we spent hours once arguing about - you're right, I'm wrong, you're right, I'm wrong, but that's part of your - you've got to do that - you've got to disagree and agree or otherwise if you always agree it's not good.

JM It helps with discussion all the same

JM Do you think that there were any disadvantages of the projects, in terms of - like you mentioned, you said that you spent hours and hours?

FL It was frustrating at times not knowing, I don't know because sometimes you couldn't exactly find what you were doing anywhere in your tutorials and you couldn't break it, you just couldn't crack the problem and you're thinking oh we'll go this way then you'd be half way through and think no, I'll change my mind now. Sometimes it's very frustrating. I don't know, you couldn't find exactly what you're doing. But that's just part of the process of learning because if you did go the wrong way you're still learning a lot and think, oh, no, no, I know what I'm doing now, and you'd go back and fix it all, but I mean, that could probably be sorted it out coming in to Uni, coming to you, asking you and a lot of people did that with the project, sort of coming in to you, hassling you a lot, and in tut times. Yeh but it just gets frustrating, I suppose, with any project but you sort of work it out and make sure its correct and move on.

JP What I found out was I didn't have, I mean apart from columns, interaction diagrams,

FL/JP? That's the only part I have problems with the columns actually, big problems. Problems, because I wasn't in the lectures to follow what happened and this and that. Every section I had problems they were not problems, question problems because there are different ways you can do it. I think if it's the wrong way of doing it you could spend hours. but on the steel part I had huge problems on the bracing part and I just did the wind loads, no problem. The bracing parts and a few others like the segment lengths, they were different all the time.

JM Do you think that you could learn using the projects on their own?

FL No, I don't think so. The projects sort of take the tutorials and lectures and sort of go further with them. There's just too much to cover in the projects and

you'd need a bit of background knowledge for just sort of reading the projects. I mean the projects were written in a manner so that anyone could pick them up and read through it and follow it and sort of understand what was going on. So we tried to write a fair bit of comprehension in ours, discussing what was going on, and a table of calculations and a summary. But as far as working some of that stuff out on your own, or just picking it up and thinking you can do it - I don't think so, because we had a hard time with the tutorials and the lectures, trying to do the projects, I don't see how anybody could just do the project.

JP Yeh definitely, I agree that you've got to have the knowledge beforehand, cause if you just walked in there it's like a big cloud and you don't know what is going on. Take all these numbers and all this and all that and I mean it's alright when you say that you just take this number, trust me, this number will work. OK good enough. It's just not the way to get the experience but if you - you have to have like the theory before you can do the practical

JM And do you think that projects are only suited to structural kind of subjects or do you think they can be used in water, geotech?

FL Projects can be used in all subjects, it's a good way to summarise everything you have learnt.

JP Its a good way to , is that what you were saying?

JM Yes, they have projects.

JP Building for people, Geotechnical 1 or 2...

JM Well it could be either I mean they could be combined, I think you had Geotech in structures which I used to have you could have a combined class

JP Yeh, No, I think it's better the way it is now, I mean the way I see it, all separate because there's too much stuff you need to know and there's too many questions that you need to ask. And for them there'll be a very short time frame for lectures to be spent on. So if they have a combined class I think you can't allow for like ten hours for this part and five hours for this part every week they'll have way too much

FL I think projects are a good way to summarise subjects because especially if you're enjoying it, you enjoy doing the project, you enjoy the subject sort of thing, you're learning things and then you apply them to say all the projects we have been doing always have been sort of real sort of things like a two storey house and doing one for Engineering for Urban Living now. Designing box gutters and all that sort of stuff, using a real place and so yeh I think they're quite effective because it's what you're pretty much going to be doing when you're working as well, sort of thing, so it's gonna sort of be similar. And I don't know, you'd be picking up little skills now as well as I think you learn a bit when you do projects. You're also constantly looking back at your notes and your tuts so it's a really good way to learn, it's pretty effective. I think

JM Anything else you want to add? No  
OK Thank you

FL Too many projects this semester though!