Integrated Design Project - An Integration of Fundamental Engineering Courses

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Abstract

Engineering has traditionally been taught by specialists as a series of separate courses, and it has been assumed that graduates will be able to integrate the knowledge and understanding gained from these diverse courses as required to undertake real world design projects. However students often experience difficulty seeing how the separate courses are related. There is therefore a need to integrate the various fundamental engineering courses to highlight the relationship between them in a complete civil engineering design project.

A final year course at the School of Engineering, Griffith University entitled "Integrated Design Project" has been developed to address this issue. This incorporates various fundamental courses such as project management, geotechnical engineering, structural analysis, concrete and steel structural design, to name a few. In addition, practising professionals as well as academics act as advisors for this course to ensure practicality of real life problems.

This paper discusses in some detail the steps involved in the development of the curriculum, the contents, the conduct and delivery process, the assessment of the project undertaken by the students and the relevant feedbacks from students' evaluation. The first offering of this course in 2004 was successful in enhancing students' understanding of relationships between different courses through the completion of the design project. Continuous improvement of the design project with more realistic features will go a long way towards students being better equipped to deal with practical engineering problems.

Introduction

Engineering has traditionally been taught by specialists as a series of separate courses, and it has been assumed that graduates will be able to integrate the knowledge and understanding gained from these diverse subject areas as required to undertake real world design projects. However students often experience difficulty seeing how the separate subject areas are related. There is therefore a need to provide some guided activity in which students learn to integrate the various courses required in a complete civil engineering design project.

This paper describe the development of a new course entitled "Integrated Design Project" in which teams of students will undertake major real world design assignments incorporating elements of project management, geotechnical engineering, hydrology, structural analysis, concrete and steel structural design, quantity surveying and costing. The rationale behind, the approach undertaken, the teaching and delivery method adopted, the design project

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developed, and the assessment and evaluation techniques exercised are all elaborated in details. Based on the successful outcome of the first offering, steps will be undertaken to incorporate students' feedback for further improvements for the next offering.

Background and Rationale

Engineering education facilitates a developmental journey that learners take in order to prepare themselves for a professional career. This development is progressed through the learning of a series of fundamental engineering courses in the first three years of Bachelor of Engineering programs. This should equip students well enough to undertake real life design problems in their final year of study. However, design of elements or segments as covered in individual courses in the final year are not sufficient enough to provide the students with a grasp of the global picture of a real life design, especially the relevance and interrelatedness of the fundamental engineering courses. This is particularly true for the existing approach at Griffith, which largely followed traditional engineering education practice. This approach suffered from fragmentation and some students tended to develop a "watertight box" mentality in which they had difficulty integrating and drawing on knowledge from more than one subject area at a time.

All these necessitated the development of the course mainly to integrate the different design components covered in different fundamental courses. Also recently Stansfield[1] reported that one of the strongest messages emerging from the Visiting Professor's scheme at the Royal Academy of Engineering, UK was that "undertaking design projects, particularly in multi-disciplinary teams, is the best way to develop engineering design ability in students. Design also provides a theme for integrating the studying of engineering and increases student motivation".

Further, the aim is to have a learning environment that encourages deep learning approach among the students. According to Bowden and Marton[2], if students deal with theory in relation to a particular professional problem situation, then their learning will be more meaningful, longer-lasting and more powerful.

Academic staff in the School of Engineering at Griffith University have been aware of the need for an integrated design approach and have attempted to implement it on a small scale within individual courses, but heavy workloads and other pressures have prevented large scale modification of the existing program structure. Note that the School of Engineering had its first batch of Civil Engineering students graduating only in 1997.

Different educational outcomes are specified by different engineering education documents[3,4,5] and documentations produced by various professional and national bodies for accrediting engineering education programs in USA, Canada, Australia[6], United Kingdom[7] and New Zealand[8]. Any engineering course developed therefore must incorporate categories of such required outcomes specific for the country in question. As such, attempt has been made to develop the "Integrated Design Project" in such a way that it ensures the development of the attributes required by the Engineers Australia Policy on Accreditation of Professional Engineering Programs[6], among the engineering graduates.

Approach and Development

Having established the rationale behind the development of a course to integrate different fundamental engineering courses, a series of steps are undertaken. This involves finalisation of the course outline, the selection of the teaching team, as well as the organisation of course structure and the delivery and assessment approach. The relationship of this course with different fundamental engineering courses covered from first to fourth year of the Civil Engineering program at Griffith is explained in a flowchart presented in Figure 1.

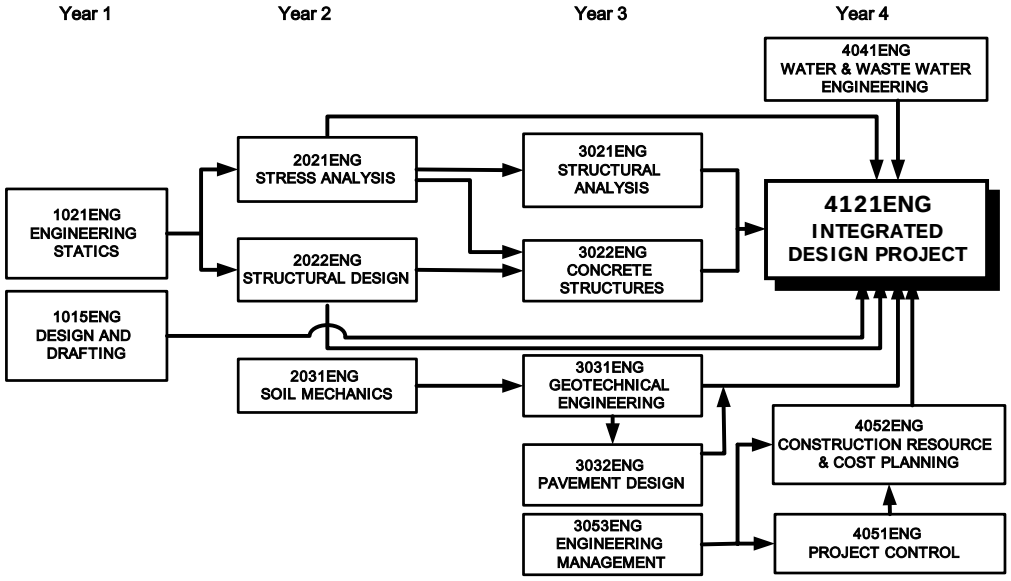


Figure 1. Relationship between fundamental engineering courses and "Integrated Design Project"

The course outline explains in detail the objectives, description, contents covered, activities undertaken by students, assessment and rationale. A copy of course outline can be accessed by every enrolling student at the beginning of the semester the course is offered.

As for the teaching team, practising professionals as well as academics served as advisors for all the student-centred design activities involved. This facilitated the students to have access to the specialists for each facet of design and to develop their ability to apply fundamentals to real world design tasks.

This course also specifically emphasises on the generic skills of teamwork, problem formulation, management skill, as well as oral and written communication skills.

Course Organisation, Teaching and Delivery Method

Based on the approach and concept outlined above and after the finalisation of the course outline and the selection of the teaching team, the organisation of the course as well as the teaching and delivery method are described herein.

The course is organised in such way that the contents are covered within the stipulated 13 weeks of teaching in one semester. The teaching constitutes, weekly, 3 hours of lectures, 2 hours of tutorials and 2 hours of computer labs. In addition, one site visit was organised to a multi-storey building construction site to familiarise the students with the on-site activities in actual construction. The detailed contents covered over the 13 weeks of lectures are summarised in Table 1.

Table 1. Course contents

Teaching week	**Contents covered**
1	• Introduction of teaching team. • Outlining of scope of course and assessment requirements. • Clarification of the design project, the steps involved, the responsibilities and submission requirements of individual groups.
2	• Clarification of Design Brief (client requirements). • Interpretation of architectural plans, balancing of functional and aesthetic factors. • Preparation of design specifications, timelines and construction schedules.
3	• Elaboration of the concept learnt from earlier studies of load estimation (dead, live and wind loads) to include earthquake loads. • Extensive practice on sketching of bending moment diagrams and deformed shapes of determinate and indeterminate structures.
4	• Optimisation of load combination. • Exploration of limit state design philosophy. • Utility of permissible stress design.
5	• Assessment of geotechnical reports. • Design of retaining walls. • Frame analysis using Spacegass and Strand7 FEA programs.
6	• Design of pavements, storm water drainage, water and wastewater drainage/system, and power supply.
7	• Evaluation of design options such as choice of materials and structural forms (client requirements, cost consideration, viability of different forms of construction).
8	• Design of civil work with consideration of economy of materials and fabrication costs and the importance of detailing for ease of fabrication.
9-12	• Detailed design of structural elements with special reference to relevant design codes. - Selection of structural types and materials; - Selection of protection systems (surface cleaning, protective coatings); - Design of composite structural elements, tilt-up wall panels, connections, purlins, rafters, columns, bracing, etc.
13	• Presentation and submission of design report.

Design Project

This course entails the development of the students' generic skills and ability to integrate all phases of a design project. These include problem formulation, feasibility study including geotechnical assessment of the site, conceptual design including architectural plans, preparation of design specifications, timelines, construction schedules, design options such as choice of material and structural form, load estimation, analysis including manual and computer methods (either frame analysis or FEA), the design of structural elements, and preparation of a maintenance manual. Typical design projects for this course could be one of the following:

(a) Complete design of a large two-storey house. The design aspects may include timber or concrete suspended floors, timber or masonry walls, sizing of major structural elements such as beams and columns.
(b) Complete design of a three-storey walk-up. The design aspects are sizing of footings, concrete slabs, and masonry walls.
(c) Complete design of a steel portal frame industrial building. The design activities include the design of columns, rafters, column-rafter connections, bracings, and selection of purlins.
(d) Complete design of a high-rise concrete building. The design activities include sizing of beams, columns, and a typical floor slab-design.

The design project undertaken by the students of the year 2004 was a portal frame building for a bus manufacturer. The client brief for this particular project is reproduced in Table 2.

Table 2. Client brief for design project of 2004

Item	Description
Client brief	The client is a bus manufacturer and wants to commission you to undertake an analysis of his requirements to provide a fee proposal for undertaking a consultancy service for him to deliver the following outcomes: • Provide the plans and specifications to ensure the delivery of a suitable building to accommodate his business; • Optimised design to best fit this building to the available site (block); • To provide services to the building; • To provide civil engineering plans and specifications required to transform the block to a profile to accept the building.
Client's intended business at the proposed building	The manufacturing process that you have witnessed on site can be described as follows: • Chassis works. In this process the stub chassis arrives to be stretched in preparation for body works; • Frame assembly. The body frames are attached to the chassis; • Wiring. The wiring harnesses are attached and fed through the frame; • Fit floor and external panels; • Fit doors and interior panels; • Paint exterior; • Underbody spray and preparation; • Fit glass to door and body; • Fit external electrics; • Fit external trimming; • Final detailing.

In this project, the students are divided into groups of four students each. Within each group, each student undertook a particular part of the design and their chosen team leader had the responsibility to coordinate the compilation of these segmented designs together. The emphasise was given on the participation of each student in a group in conducting their design work as well as oral presentations. This was ensured by checking the progress of work during the tutorial classes. A concept of "benchmarking" was introduced for this purpose as explained in the next section.

Assessment and Evaluation

In this course, the student performance was assessed according to the breakdown shown in Table 3. The ultimate goal of the design project is to produce a detailed design of the specified building structure incorporating all aspects of civil engineering design. To ensure timely completion of the assignment, a set of benchmarks were established. At each benchmark, students were required to submit all necessary calculations and drawings, as well as relevant discussions. Students were also permitted to make changes and corrections to their work following an initial review.

This was done because assessment results alone do not explain student's learning problems[9]. The benchmarking approach was therefore designed to evaluate whether the design and delivery of the course have helped foster student learning and to check on students' acquisition of basic concepts, understandings and skills, and also to see whether students are using "deep" or "surface" learning approaches in this course.

In addition, students were also required to make an oral presentation on their design. In the presentation, each student was required to summarise his/her design and provide an explanation for the decisions made. The presentation was followed by an open discussion through which the advantages and disadvantages of the design can be examined.

Table 3. Assessment details

Item	Description	Weighting (%)
1	Design project report	40
2	Oral presentation	10
3	Final exam	20
4	Computer related analysis tasks	30

The assessment rationale is that the project report assesses students' written communication skills and the presentation assesses their oral communication skills. Both of these assessment items also assess problem identification, formulation and solution, analysis and critical evaluation in a team context, as well as leadership, responsibility and their grasp of ethical issues.

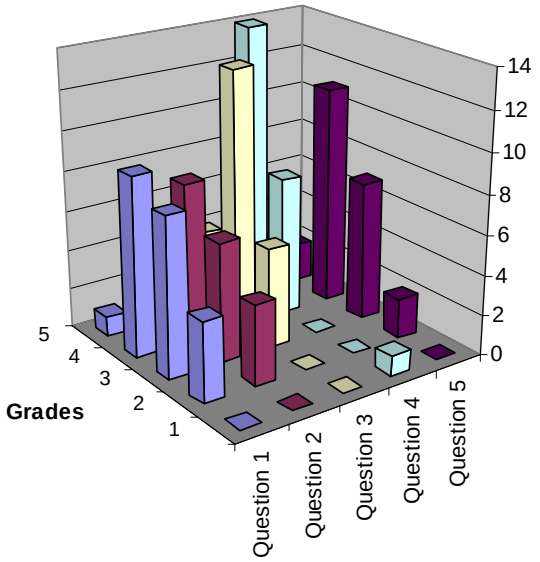
Furthermore, the design project was selected in such a way that there are combinations of different structural types/elements. This allowed group comparison which has helped students better understand the performances of different designs. This in turn also helped to achieve consistency in both qualitative and quantitative measurements in student learning outcomes.

As per the University requirement and also for making improvement of the course offering, students' evaluation survey was conducted at the end of the semester, in which the course was offered. This will facilitate reflective measures to be undertaken for the further modification of the course in the next offering. Because reflective practice is the basis of effective professionalism in whatever area[10], including university teaching[11,12]. Reflective practice can be formally encouraged and directed as 'action learning'[13,14]. Essentially, action learning is being systematic about changing teaching approach and making sure that the changes are in the right direction.

The relevant questions from the questionnaire for the students' survey are presented in Table 4 and the students' responses are plotted in Figure 2.

Table 4. Relevant students' evaluation questionnaire

No.	Question
1	Class sessions and workbook notes were organised to ensure maximum learning.
2	The course objectives and assessment requirements for each session were clear.
3	The staff member was organised, well prepared, and explanations clear.
4	The staff member encourages questions and seemed willing to offer individual help.
5	Overall- How would you rate this course.



(Note: Grades 1-5 stand for "strongly disagree", "disagree", "neutral", "agree" and "strongly agree")

Figure 2. Student evaluation results

In addition, students were asked to give their comments in the evaluation. Some typical responses are highlighted as follows:

- "The course was very challenging and upon finishing the assignment I felt as though I had achieved something".
- "It also provided a great insight into the design methods used in a design office."

- "I developed a practical understanding of how loads are transferred throughout a portal frame structure. More time could have been spent on the methods for analyzing the way in which a structure acts as a whole, as it is new information, and I found it to be interesting and practical."
- "Students working together in a group for this course was much more effective than working independently and continually getting stuck on a problem."
- "In general I thought the subject was very worthwhile, allowing students to work through a real life scenario. It also allowed us to use some of the design tools (i.e. charts) that are now commonplace within the engineering profession."
- "More time could be spent on learning to make assumptions such as deflection limits for ultimate and serviceability cases. Many assumptions were required in the design project and exam and it was difficult to know what limits to take without enough design experience to realistically assume different things."

Conclusion

To fulfil the burning and long-standing need of integrating fundamental engineering courses into one practical oriented single course, a new course entitled "Integrated Design Project" has been developed at the School of Engineering of Griffith University in 2004. Described herein in some detail are the steps involved in the development of the curriculum, the contents, the conduct and delivery process, the assessment of the project undertaken by the students and the relevant feedbacks from students' evaluation of this course.

In general, the first offering of this course was successful in enhancing students' understanding of relationships between different courses through the completion of the design project. Efforts will be undertaken to incorporate the students' feedback in the next offering. Continuous improvement of the design project with more realistic features will go a long way towards students being better equipped to deal with practical engineering problems.

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