

Project management: learning by doing

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Abstract

The University of Waikato introduced a four-year Bachelor of Engineering with honours programme in 2000. Graduates must have the appropriate hard and soft skills to enter the profession. These soft skills include being able to function in a team environment, using individual team member's expertise, managing projects, an understanding of ethics and standards, and supervisory skills. This paper describes how senior engineering students develop project management skills by being project managers for a team of Year 1 students undertaking a design-and-build project. This gives them the opportunity to work on a 'real' project, with financial and time constraints. The process is structured to provide an effective learning environment without compromising the independence or open-ended nature of both the Year 1 and Year 4 student's experience. The senior students act solely as project managers and are not allowed to contribute directly to the design or assembly of the project. The project management module, which is 10% of the *Honours Research and Management Project* in Year 4 (5% of the final year's grades), is assessed by the quality of written agendas and minutes, completing the project on time and within budget, and a reflective essay on their learning. Outcomes of assigning a project manager to each team include: Year 1 teams meeting project milestones without involving excessive supervision from academics; monitoring and encouraging participation from all team members; Year 1 students have formal contact with their older peers, who act as role models and can serve as mentors; Year 4 students gain experience and earn credit for project management; the possibility of increasing contact between Year 4 students and academic staff, with students experiencing the realities of management, teaching and mentoring in university life.

Key words: project management; capstone; teamwork; cross-disciplinary; design-and-build

1. Introduction

New Zealand engineering degrees are accredited by the IPENZ Engineers New Zealand (IPENZ), the Registration Authority of professional engineers in New Zealand. This organisation is responsible for ensuring professional and engineering standards are maintained. Academic standards are ascertained through an accreditation process, involving a

panel of national and international academics and industry people assessing individual engineering programmes. Accreditation provides independent confirmation that graduates have acquired the skills and attributes the engineering professions and international Accords require. Thus, accreditation is outcome based rather than based on prescriptive descriptions of course content. In New Zealand, the four-year Bachelor of Engineering (BE) programmes are internationally benchmarked under the Washington Accord. The accreditation documentation¹ itemizes the graduate capability profile. It includes 'hard' skills such as understanding and applying mathematical and engineering sciences to an engineering discipline, formulating and solving models that predict the behaviour of part or all of complex engineering systems, demonstrating the efficacy of solutions to part or all of complex engineering problems, recognising when further information is needed, etc., and 'soft' skills such as project management, people management, communication, comprehension, written communication skills for effective reports and design documentation, working in teams, etc.

Curriculum developers have the challenge of identifying and developing generic and specific competencies in their students that will be useful when graduates enter the workplace. Engineering student need suitable environments to develop the relevant technical knowledge and skills and then be able to integrate this knowledge and skills with personal qualities so they can deal effectively with unfamiliar and familiar situations or tasks. An early educator² suggested that learning occurs from problem-solving in authentic environments the learner faces. Competency in the workplace is a combination of cognitive skills and personal or behavioural characteristics³. New Zealand studies on cooperative science and technology programmes⁴⁻⁷ list 24 hard and soft competencies that could be important in the workplace. Most employers of the technology students considered all 24 competencies are important, although there may be emphasis on the 'hard' skills⁴. Some skills may be obtained in the classroom but others are best developed via work-based learning.

The 'soft skills' such as report writing, working in teams, ethics, social awareness required of a professional engineer are developed in many of the papers in Waikato University's BE(Hons) programmes, with increasing emphasis on including these aspects the student progresses through the programme. Although most senior students have usually completed their co-operative industrial engineering experience before they enter their fourth year, they often have no experience of project management. Due to time and resource constraints, project management is often taught by lectures or by using case studies. Theoretical lectures on this topic can be uninteresting so the University of Waikato introduced a practical project management module into the Year 4 *Honours Research and Management* paper where the senior student manages an interdisciplinary team of Year 1 students. This provides a project management experience for the students and facilitates learning through hands-on activities.^{8,9}

2. Course overview

The University of Waikato introduced the BE(Hons) degree in 2000. This four-year degree is offered in six programmes - Biochemical Engineering, Electronic Engineering, Materials and Process Engineering, Engineering Science, Mechanical Engineering and Software Engineering. The first three programmes have provisional IPENZ accreditation and will be subject to full accreditation in 2006. The programmes have five common subjects in the first year, with the remaining three Year 1 subjects being appropriate for the specific programme. There is increasing specialization as the student progresses through their chosen programme, but all programmes have interdisciplinary design papers at Year 2 and Year 3. Each programme has a capstone *Honours Research and Management* paper, made up of an

individual research project, a team design project, and a management module. This paper is half of the final year course work and demonstrates that the student can work on open-ended problems as well as specific research projects. Each programme also requires 800 hours of industrial experience through a co-operative education programme.

3. Foundations of Engineering paper

All first-year students doing the BE(Hons) degree at the University of Waikato enrol in the interdisciplinary paper *Foundations of Engineering*. This 15-credit paper (equivalent to one-eighth of the year 1 programme) introduces students to engineering analysis, engineering design and the engineering profession. It describes the skills of a successful engineer, the nature of design and the design process, and the fundamental laws for engineering analysis including principles for mass, energy, charge, momentum. The paper also includes a laboratory component and a design-and-build project. The former component contributes 8% and the latter component 22% to the final grade of the paper. During the first set of three-hour laboratories, students measure and assess the properties of materials and assemblies relevant to the design project, and are taught basic computer-aided design (CAD). The last six laboratory sessions involve designing and building a project to specific design criteria and within time, material, and budget constraints (Table 1). Projects undertaken have included designing and building 1-metre yachts and speed boats. The final task in the project is to race the boats on the university lake.

In 2005, 110 students were enrolled in Year 1 (including some BSc students) and 19 in Year 4. These numbers are projected to grow to 140-150 Year 1 students and 60-70 Year 4 students. Five to eight Year 1 students are allocated to each design team, ensuring each team has an appropriate mix of the six engineering disciplines. Some adjustments may be made to ensure a balance of ethnicity and student academic ability. Then, senior students are allocated as project managers for a single team. The matching of senior student and team depends on the senior student's timetable for their other taught papers. To date, there has no scheduling problems matching senior students (number and availability) with the number of teams in each laboratory.

4. Honours Research and Management paper

The capstone *Honours Research and Management* paper is normally completed over two semesters, although individual students may occasionally complete it in a single semester. There are three components in this paper - a project management module (10%), an individual research project (30%), and a team design project (60%). The latter component involves synthesis of a major process or product, utilising the full range of knowledge required for professional practice and is done in groups of up to three students, with each group handing in a single report. The remainder of the Year 4 programme involves taught papers appropriate to the specific engineering programme.

The project management module involves lectures on various topics such as project management, hazard analysis, engineering and professional ethics, technical writing, and the engineering profession. Many topics are given as lectures or case studies throughout the year, often by practicing professional engineers. The project management module is assessed on activities associated with being a project manager for a team of Year 1 students carrying out a design-and-build project. The senior students have the opportunity to work on a 'real' project, with finance and time constraints. They act solely as project managers and are not

allowed to contribute directly to designing or constructing. The process is structured to enable an effective learning environment without compromising the independence or open-ended nature of the Year 1 or Year 4 student's experience.

Table 1. Summary of specifications and criteria for the Year 1 design project in 2005

Item	Criteria
Number of boats	2 speedboats per team (not necessarily the same design)
Design Specification	<ul style="list-style-type: none"> • Maximum width - 400 mm • Maximum length - 700 mm • Front 10% (by volume) of the boat must be filled with expanded polystyrene • Maximum nominal voltage - 7.5V • Sensitive components must be housed in water-tight compartments
Budget	Total of \$450.00 Some materials are bought outright; other items can be hired or leased
Work Rules	<ul style="list-style-type: none"> • All construction work to be done in laboratory time using only the tools provided • Safe work practices must be used, and appropriate personal protective equipment used (the technical staff have authority to stop any work that is unsafe)
Race day	<ul style="list-style-type: none"> • June 10 (last day of semester). • The competition is of a series of races (rather than time-trials), with a set of Race Etiquette rules • Each boat participates in two heats, with progression into the quarter-finals and beyond based on best times
Penalties	<ul style="list-style-type: none"> • Unsafe work practices or inappropriate use of tools when constructing the boats – a time penalty of 5 seconds for each infringement is imposed on both boats in the first heat. • Penalty 360° turns are required for boats that breach the race day rules
Assessment	<ul style="list-style-type: none"> • One report per team. • All members in the group must contribute to the final report and individual team member's contribution must be clearly identified (this allows for variation in individual marks) • Contribution to team work. Project managers (Year 4 students) are surveyed on the contribution individual team members make to the overall project

A competent senior student should spend about 100 hours on the project management module, which includes attending lectures and departmental research seminars, researching, organising and holding planning meetings, writing agendas and minutes, researching project management techniques, and writing the reflection essay to evaluate their learning in the module and placing this learning in the context of competencies that will be useful when they enter the workplace.

The project management module begins with two introductory lectures on project management given by a senior academic with industrial management experience. This is followed by discussing two case studies. At a further lecture, the assessment components (Table 2) and assessment criteria for the module are discussed. Aspects of running a meeting, how to motivate team work, and the aims, specifications and rules for the design-and-build project are also discussed.

Table 2. Project Management Module Components and Contribution to Grade (2005)

Component	Number	Contribution to grade, %
Example agenda	1	4
Meeting minutes	8	24
Performance on race day	1	22
Reflection essay	1	50

The learning outcomes of the project management module include: being able to identify and allocate the people, resources and time elements of a project; learning to write a technical report; and identifying and developing project management skills with minimal supervision from the course coordinator. A further outcome is being able to evaluate their learning and place this in the context of competencies required for project management.

5. Implementing the project management module

The first project management meeting is scheduled during a laboratory session and is used for team introductions, for team members to state their individual capabilities, and to engender team spirit. The goal is to get the two boats designed and built, ready to race within six 3-hour laboratory sessions within six weeks. Before the actual building begins, the Year 1 students are learning CAD (Pro/Desktop, Parametric Technology Corp.) and carrying out preliminary trials on aspects of various boat components such as observing the behaviour of different propellers, investigating forward and lateral drag of hulls in flow tunnels, measuring the capabilities of different drive assemblies and measuring motor efficiencies. Project managers have an extra logistical complication at the start of the project because each Year 1 team has been divided into two. One group is learning CAD while the other group is carrying out preliminary trials to assess performance of boat components. The groups alternate their activities in the first four laboratory classes. The remaining project meetings can be scheduled during the laboratory or held outside the laboratory time.

Year 4 Students submit a meeting agenda before holding their first meeting so the coordinator of the project management module can check that all elements will be addressed - introductions, project brief, design and budgeting constraints, rules for purchasing materials, deciding how to research possible designs so the team can make considered decisions, identifying and allocating tasks, ensuring that teamwork is stressed, selecting a name for the syndicate, and deciding how the team will communicate with each other. Each team is initially allocated a letter of the alphabet and choose a country starting with that letter. If the team chooses to use the University's e-learning environment - ClassForum - the Year 1 coordinator sets up the 'discussion' groups. Alternatively, the team can communicate by email. Many teams choose to have their planning meetings outside the scheduled laboratory time to ensure team members have a clear idea of what needs to be done, and allow the maximum time for construction.

Project managers of each team submit electronic or hard copies of minutes of subsequent planning meetings for assessment. Feedback is given on what has been done well and what has been overlooked.

6. Discussion

This teaching method has been used in the four years since the degree was introduced, using academics from the Department of Materials and Process Engineering. We consider that we have got a working system and the next step is to identify an appropriate assessment method and involve academics from other departments that teach the BE(Hons) degree. The academic coordinating the project management module does not give specific rules on how the project managers should run their meetings or their project but will offer advice if the team is not making good progress. The Year 4 project managers are responsible for identify tasks, project scheduling, review meetings, and budgeting.

To keep project managers on track, we found that it is very important to ensure they have appropriate, timely feedback. At present, this is via prompt marking of the minutes (preferably within 24 hours). A set marking schedule is attached to each set of minutes with tick boxes to indicate whether the project manager has: met the hand-in date (within two days of the meeting); indicated the organisation and meeting type; given the date, venue, start time and closing time; noted the team members present and accepted apologies; checked minutes of the previous meeting; listed things discussed and action points that have arisen; and noted the next meeting time and venue. Comments are given on length, content, points overlooked, good points, and things to considered for improving the minutes: By doing this, we attempt to address writing style.

We have made the following observations on this technique for teaching project management. At the beginning of the module, most senior students appear to have little experience with project planning and find it difficult to identify individual tasks in a complex project, assessing time lines and estimating the budget. They find it difficult to match resources, people and time and often say “we’ve had no experience of this before. That’s why we are not doing well”. As the project deadline approaches, there is increasing realization that many tasks have not been identified and/or allocated an appropriate time. Information in the minutes as the project progresses indicates that project managers gradually become aware that good planning helps make the project go more smoothly, and also helps get the best out of individual team members. Minutes change from being a list of ‘supervisory’ tasks for the immediate laboratory session to longer-term planning. Project managers learn how to ensure that team members turn up to their meetings so everyone knows what is happening. The quality of the written minutes also improves as students assimilate the reasons for suggested changes in layout, grammar and technical writing style. We may need to introduce ‘review meetings’ to ensure that all project managers are addressing the project management processes¹⁰ and are on track to meet the completion date for the design and build project.

The Year 1 students gained informal mentoring from their Year 4 counterparts. Academics running the project management module and the Year 1 laboratory observed that the Year 4 students used the project management meetings to comment on: differences between individual engineering programmes; content of papers in subsequent years; workloads; strategies to interact with academics; work placement and engineering experiences; and social events for engineers.

Information from the reflection essay each senior student submitted after completing the project management module showed the following main points: students had become more aware of the need for team work to ensure a successful project outcome; it was important to ensure that all members are contributing equally; and they gained an appreciation of budget control and project time lines. An important benefit was the inter-disciplinary emphasis due to the design project brief, and the hands-on experience of managing a team. These emulate what will happen in a real engineering environment.

In previous years, very little criteria have been provided for the reflective essay on the student's experience with project management. In 2005, this will be more detailed so learning outcomes can be measured and the effectiveness of the teaching method used for this module evaluated.

7. Conclusions

The project management module gives senior students a realistic experience of managing a complex project to defined time and money constraints as well as allowing them the opportunity to develop team building and management skills. Outcomes of assigning a project manager to each team have included: ensuring the Year 1 students meet various project milestones without demanding excessive time from academics; individual management of each team helps monitor and encourage full participation from all team members; Year 1 students benefit from contact with their older peers, who act as role models and can serve as mentors; the spirit of engineering is engendered, giving opportunities for older students, who run the engineering society, to encourage younger students to take part in social activities; the Year 4 students get real experience and earn credit for project management in one of their final-year courses; and a closer relationship is forged between Year 4 students and academic staff, with students experiencing the realities of the management, teaching and mentoring in university life. The next stage is to develop methods of assessing of this learning experience.

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