Problematic project work in a first year course – sustainability for civil/infrastructure and environmental engineers

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Abstract: In 2004, the School of Civil & Chemical Engineering at RMIT introduced a new program in civil and infrastructure engineering ([1],[2]). This renewed program moved away from a traditional view of civil engineering based around design of new structures towards a whole of life view of infrastructure and the concomitant design challenges. In this new program, students do project work in each semester in an Engineering Practice course (subject). This paper reports the challenges of introducing concepts of sustainability, design, groupwork, report writing, logbooks, seminars, etc within a project based approach in first year during 2004 and 2005 in one of those courses, Environmental Principles for Sustainable Design. Lessons learned so far and intended changes for the second semester of 2005 are described. We need to include the environmental engineers in the abstract somehow…

Overview

Project-based courses, particularly in first year, are very demanding for both the students and for the teaching team. In our experience, many students are initially very dependent on the teaching team for detailed definition of what is required in the tasks, with some focusing only on work that has marks attached. Some students have more focus on the tutorials than the lectures (on sustainability), and many have trouble 'breaking through' the common view that economics (alone) is what drives decisions in engineering.

In 2004 semester 2, students struggled with applying the practices that were introduced in first semester to the project, as well as connecting material from other sources into their project work. Of particular concern was the inability, or unwillingness or lack of recognition of the need to:

- Use a systematic problem solving or engineering design process in the project
- Use the material of the lecture series
- Use previously taught report writing skills
- Work in teams

This paper describes our struggles with these issues, including progress made and plans for the future.

Capabilities

The new civil and infrastructure program was designed around graduate capabilities ([3]). These were derived from the graduate attributes required by Engineers Australia ([4]) combined with a series of meetings with industry representatives. See the list of capabilities for the civil program in the table over the page. For more details of how these capabilities were developed, see [2].

Dimension of Capability	Descriptor
Personal Development	· Be conscious of their own values · Adhere to professional ethics · Plan their career · Reflect on experience · Improve their own future practice · Engage in Lifelong learning
Sustainability	· Balance the technical, economic, environmental and social demands of a problem · Protect safety, health, and welfare.
Problem solving and decision-making	· Model engineering problems using a systems approach and appropriate assumptions · Use brainstorming and other idea-generation techniques · Use a range of decision making (evaluation) methodologies · Identify the criteria to be used in decision making (eg sustainability) · Use a range of engineering analysis tools (see Technical Competence) · Use data and information to support decision making · Access information from a wide variety of sources, discern value and use · Operate a range of software
Technical competence (engineering analysis)	· Conceptualise, plan, design, construct and manage civil infrastructure systems. · Perform a range of engineering analysis techniques · Analyse and interpret field and laboratory data. · Be familiar with the elements of building, facilities, process and system design. · Design and conduct experiments
Teamwork and Leadership	· Operate within an engineering organisation · Manage projects and contracts · Develop quality plans · Work in a team · Define goals and normal behaviours in a team, eg be respectful and tolerant of others · Provide constructive feedback to team members · Resolve conflict in a team · Lead a team · Work with other disciplines in a team with conflicting needs
Communication	· Communicate effectively, that is, to listen, observe, speak, draw and write · Communicate results qualitatively, quantitatively, graphically, electronically, textually · Communicate processes of thinking and reflection (including giving constructive feedback)

CIVE1186 Objectives

These capabilities are designed to be developed over the four year program. Within CIVE1186, Environmental Principles for Sustainable Design, the learning objectives were as follows ([5]):

On successful completion of this course, you will be able to:
1. Explain how the need for environmental policy and codes of practice developed.
2. Recognize environmental issues pertinent to projects and prepare a basic Environmental Effects Statement.
3. Develop a conceptual design for a simple engineering project, which addresses sustainability aspects in all phases of the project.
4. Explain the principles governing environmental best practice.
5. Debate environmental issues within the context of sustainable professional practice.

Technical capabilities include:
• Conceptualise projects in a sustainable context in all phases i.e. planning, design, construction and operations
• Recognise the role of environmental policies and codes of professional practice

• Evaluate the environmental status of projects
• Perform a range of engineering analysis techniques

Non-technical capabilities in personal and professional development, communication, teamwork and problem solving will also be developed through the team project.

The course design

This particular course, although new for the civil and infrastructure engineering (from 2004) and environmental engineering students (from 2005) was based on an earlier course, Environmental Principles, taught as part of the original environmental engineering program at RMIT ([6],[7]). This lecture-based course of 6 credit points comprised one half of the new course of 12 credit points. A project-based component makes up the additional 6 credit points.

The lecture series gives a robust introduction to environmental policy and its history through a range of case studies. Students undertake a written assignment where they must compare and contrast several articles about environmental issues. An exam tests basic understanding of the issues.

The project immerses students in having to integrate sustainability principles in an engineering design. In 2004 (semester 2), students were asked to redevelop an old bakery site (heritage listed) into a suite of apartments, offices and shops, while demonstrating a commitment to sustainability principles. In 2005 (semester 1), students were asked to investigate development options for Westerfolds Park in Melbourne's suburb of Templestowe, again using a sustainability framework for decision making. These projects were intended to develop the objectives and capabilities discussed above, in conjunction with the lectures.

2004 Plans

The teaching team devised the following plan for the semester as follows. The highlights and lowlights of the semester follow.

WEEK	THEME	ACTIVITY
1	Getting started on group-work and sustainability	Introduction of project brief. Form into groups of five (with new people, balance between leaders and followers) Getting to know you – at least names, contact details. Assess capabilities (individual and group). Discussion of project in groups. Discussion of sustainability – what does it mean for us.
2	Collaborative Group-work Mapping the system People	Collaborative group-work video – key message – getting to know each other is important, allow time for group formation. Presentation of sustainability posters. Project site as a (socio-technical) system – develop models in groups. One-minute presentation of group-work
3	About the site Design Process	Review of design process Existing structure – how do we find out if we can use it? One-minute presentation of group-work Share information about the site. Work on the project.
4	Critical Analysis –People	One-minute presentation of group-work Interview techniques Critical analysis activity People using the building activity Work on project
5	Getting to see what others have done	Field trip
6	Recycling and waste	Set-up roles for community consultation

WEEK	THEME	ACTIVITY
	management	One-minute presentation of group-work Work on project Share information on Recycling and waste management
7	Community Consultation	Presentation of proposition, including role play
8	Energy Systems Heating and Cooling	One-minute presentation of group-work Work on project Share information on Energy Systems, Heating and Cooling
9	Insight into Sustainable Construction	Expert in Sustainable Construction. One-minute presentation of group-work Work on project.
10	Water conservation, storm water & waste water	Set-up "Issues of Sustainability" groups One-minute presentation of groupwork Work on project Share information on water conservation, storm water & waste water
11	Searching for Consensus	Activities on issues of sustainability and achieving consensus. One-minute presentation of group-work Work on project
12	Presentation	Final Report presentations to Board of Directors
13	Review	Review of project work and sustainability. What have we learned?

2004 Highlights of the Semester

This was the first offering of this course, combining the original Environmental Principles with a suitable sustainability project. The project, which was a re-development of an old bakery site using sustainability principles, was a good 'fit' for the renewed Civil and Infrastructure program's focus on sustainability and redevelopment of existing buildings and infrastructure.

Regular presentations with feedback, as well as re-submission of sub-standard work and coaching meant that by the end of the semester, most groups produced very good presentations and reports.

The visit by two young practicing engineers, one a structural engineer and the other a transport engineer, was a highlight for the group; students asked many questions and showed they had developed some insight into their careers.

The site visit to the 60L green building or other more sustainable building sites was again a highlight for the students; they saw that it was possible to implement more sustainable practices in the real re-development of a building. There was much call for more practicality and examples in the course.

The log-books, which were collected twice in the semester, were a fabulous source of information on where the cohort and individuals were 'up to' in this program. It allowed the teaching team to acknowledge issues in the cohort and of individuals and to find and implement solutions to these issues.

2004 Lowlights of the semester

Students struggled initially to get going with the project. Initially, they seemed to be waiting; there was an expectation that we were going to 'teach' them the material for the project; thus, much of the earlier work in the project was very poor and **students had done little research** to support their ideas. It took some time for students to realise that we expected them to research the issues of sustainability around the project for themselves.

When we shifted to provide them **more structure** by doing exercises in applying project management techniques and requiring intermediate deliverables to the project they were more able to come to grips with the project work and progress was made.

We also had to link these intermediate **deliverables to marks** to capture students' interest. This was problematic as we were trying to get them to be independent learners; by introducing marks for the intermediate deliverables some students became driven by marks rather than by their interest in the project and their learning.

More difficult to shift was their inability to **generate alternatives** for their designs and for the solutions to the sustainability issues and also how these solutions might be applied to their design, including re-design. Once they found one design or solution they locked onto it and were reluctant to consider other possibilities. There was a rush to complete rather than 'open up' the design and solutions.

The students made **few connections** between the lecture series and the project work; rarely was the material of the lecture series explicitly or implicitly mentioned in the project work.

Some students **objected to using the logbooks** – they had difficulty seeing the value to themselves. Others saw the value once they had begun to put some of their thoughts on paper.

For some groups or individuals the **groupwork was problematic**. Some of these groups split the task up between the members, wrote separate pieces and then collated the pieces; there was very little integration of effort. Other groups had difficulty with dealing with problems in groupwork, such as individuals that didn't do their share of the work, or did work that wasn't up to standard. We offered the cohort a peer assessment technique and the ability to have a weighting scheme applied to the marks based on the peer assessment. The vocal students objected to this as they felt it might affect their friendships. Group marks were given for the final report and presentation in all but one case.

International students – poor performance from a significant proportion of international students continues in spite of course material, tutorials and straight forward exam questions with plenty of choice. The English language skills are clearly inadequate in some cases and from past experience this has proved to be a major impediment to these students in their engineering studies. In this aspect the course is a good indicator of future performance and perhaps gives some basis for reflecting on selection criteria or the need for some other mode for these students early in their careers.

Proposed Improvements for 2005

In future semester-long projects, students need a more structured approach. We have developed a project flow diagram that shows intermediate deliverables of the project, to help students work more consistently through the semester. The key stages of project completion are:

- Planning the project, deciding on tasks to be completed and time required
- Research and defining the problem – what is really required?
- Generating alternatives and selection criteria
- Analysing the alternatives against the criteria using a sustainability framework
- Choosing a preferred alternative and making a recommendation
- Documenting the process

Each of these stages produces documentation. Students must submit a brief report as outcome from the process plus (usually) present a summary to the class.

In 2005, this course was even more challenging because it moved into first semester, as well as having a combination of environmental engineering and civil and infrastructure students. Students need special care with project management as well as report writing, presentation and teamwork skills, at the same time as developing their understanding of engineering and their chosen branch.

Further, the choice of project needed care to take into account the interests of the two cohorts. On the other hand, the environmental students bring a more enquiring mode while the civil students bring a more 'let's get on with it' approach; this variation brings some opportunities to the course work.

In first semester 2005, we decided to do initial work in pairs rather than groups, with later work in pairs of pairs (groups of 4) in second semester. With pairs, the students only have to 'get on' with one other and the ability of the students to hide in a group is reduced.

Since research was a major problem in 2004, we decided that each tutorial class would act as a research consortium, with each pair of students researching just one out of a dozen or so topics (water, energy, flora and fauna, regulations, building materials, …).

2005 Experience

For 2005, students received more scaffold ing to walk them through the engineering design process. A Project Handbook ([8]) has been prepared that describes the basic skills that we expect them to use:

- Engineering as problem solving
- Project Management
- Groupwork
- Logbooks (note keeping) and Journal wr iting (reflective writing)
- Report writing and Referencing
- Oral presentations and Posters

Staff acted as project managers, marshalling the skills of the class to get the project done. Through this approach, students should see the design process in action.

In the first tutorial, we got them to look at what engineering is for them and to develop posters in groups for presentation in week 2.

In the second week, they wrote a paper about sustainability – to understand what they understood of sustainability and also to assess their writing skills and identify those that should be directed to the Learning Skills Unit for some English language coaching.

We tried to link the lecture series (and its field trip to Westerfold's Park) more closely to the tutorial serie s through the project work. The project was to design a sustainable development for Westerfolds Park. We organised the tutorial series as structured research using the project flow diagram (see Appendix), with clear deliverables (Briefing Papers, Feasibility Paper, Alternative generation, Selection Criteria, Final Report etc). We provided a plan for the whole semester in the first week, so that students could see where we were going (if they wanted to. Note that many seemed to misplace this or failed to bring it to class on a regular basis).

In the first half of the semester, the students worked in pairs developing the briefing papers – the work was distributed across each tutorial group. Each pair had a topic (water, building materials, energy, regulation, etc) that they needed to research and report on for the group. They presented this briefing material to the whole tutorial class and got some feedback about

their ideas. They also posted these papers on the Distributed Learning System (DLS, a Blackboard site), so each class also had access to the work of the other four tutorial classes.

Each pair then reviewed another pair's briefing paper. They had to revise their briefing paper in the light of this feedback, including feedback from class discussion. Each pair then produced a feasibility paper by synthesising all of the briefing paper topics (about a dozen topics in all).

The students were then grouped into pairs of pairs; they were given the opportunity to form groups with students that they hadn't worked with before. We then moved to generating alternatives for each of the options, developing selection criteria and assessing the options against the criteria, writing a final report and putting the proposals before a review panel of community representatives (role play).

They were asked to keep a logbook. This had the dual role of keeping track of their work and also as a space for personal reflection on the learning process. We viewed the logbooks at mid-semester in order to provide feedback and then at the end of semester as part of the assessment process.

At the end of the semester, the students were asked to write an Evaluation Report. This was modelled on Engineers Australia's Career Episode Report for Chartered Professional Engineering status. This two column format placed learning objectives (capabilities) in one column. The second column is used by each student to demonstrate how they met each learning objective.

Even though we attempted to link the lecture series with the tutorial series we don't think this worked. We need even closer ties between these two parts of the course. The students currently experience them as quite separate, with seemingly two sets of (independent) assessment tasks. Some found the lecture series hard to come to grips with – it all merged into one, difficult to distinguish what was important; it didn't get directly applied in the tutorial or elsewhere in the program.

There was some lack of engagement in the site visit to Westerfolds Park – the site visit reports often covered only part of the material covered (10 sites but only 4-5 covered). Many complained that they couldn't hear, but none made any comment that they had done something about this.

We think that the Westerfolds Park project was too 'remote' for young adults who are mostly (85%) men, and does not link directly to their interests. Alternative projects are being considered for the future.

One student saw the tutorial series as a series of projects and asked that we provide one project!

Issues that students identified include:

- time management (particularly when producing reports under pressure). They tend to split the work up to individuals then collate an hour or two before it's due.
- They don't synthesise the report into a whole, read through it to make sense etc.
- They did not understand what depth to go to in research.
- Their drawing and sketching skills were minimal.
- Their writing skills primitive in many cases (including Australian students).

Their presentation skills improved over the semester as they grew more comfortable in their tutorial class. Some indicated by the end of the semester that this had been a good experience for them – forcing them to practise their speaking skills.

Many/most remain complacent about their study. They are driven by marks and expect staff to drive them. If there are no marks, why do anything? It takes sometime for them to become responsible for their own learning.

Evaluation of Student Engagement

Ahlfeldt et al ([9]) developed a simple survey of student engagement based on the US "National Survey of Student Engagement ([10])". The survey evaluates three areas: collaborative learning, cognitive complexity and gains in personal skills. These are summed to give an overall "engagement score".

Table 1 – The Ahlfeldt Survey:

Collaborative learning				
During your class, about how often have you done each of the following? **Scale: 4: very often; 3: often; 2: occasionally; 1:never**				
1. **Asked questions** during class or contributed to class discussions	4	3	2	1
2. **Worked with other students** on projects during class time	4	3	2	1
3. **Worked with classmates outside** of class to complete class assignments	4	3	2	1
4. **Tutored or taught** the class materials to other students in the class	4	3	2	1
Cognitive complexity				
To what extent has this course emphasized the mental activities listed below? **Scale: 4: very much; 3: quite a bit; 2: some; 1: very little**				
5. **Memorizing** facts, ideas or methods from your course and readings …	4	3	2	1
6. **Analyzing** the basic elements of an idea, experience or theory …	4	3	2	1
7. **Synthesizing and organizing** ideas, information, or experiences into new …	4	3	2	1
8. **Evaluating** the value of information, arguments, or methods such as …	4	3	2	1
9. **Applying** theories and/or concepts to practical problems or in new situations	4	3	2	1
Gains in personal skills				
To what extent has this course contributed to your knowledge, skills, and personal development in the following ways? **Scale: 4: very much; 3: quite a bit; 2: some; 1: very little**				
10. **Acquiring job or career related** knowledge and skills	4	3	2	1
11. **Writing** clearly, accurately, and effectively	4	3	2	1
12. **Thinking** critically and/or analytically	4	3	2	1
13. **Learning effectively on your own**, so you can identify, research, …	4	3	2	1
14. **Working effectively with other individuals**	4	3	2	1

The survey was used by Ahlfeldt et al to evaluate a wide range of classes in various years and various disciplines, including classes that used PBL. The results showed that significantly higher engagement scores were achieved in more senior classes, smaller classes, classes using PBL, and arts classes (as opposed to science classes).

Because this course ran as two separate components, namely a 3 hour lecture series and a two hour project-based tutorial each week, it was decided to ask students to complete a survey for each component. Our hypothesis was that there would be a distinctly higher level of engagement in the project-based tutorial than in the lectures.

At the time of writing, 87 responses were available out of 125 class members. The comparison of means shows a clear statistical difference between the means ($p=2.4 \times 10^{-9}$). The hypothesis that the engagement in tutorials would be greater than in lectures was clearly supported.

Further discussions of this use of this survey are provided in a companion paper ([11]).

Plans for Semester 2 2005

Semester 2 2005 Engineering Practice course theme is 'skills for engineering'. We are hoping that now the students have been through the process of designing a sustainable development in Semester 1 that they will be able to see some of the skills that they need to develop.

There has been interest expressed in the students being able to choose their own project next semester. The rationale for this is that we may be able to get closer to the students own interests rather than trying to concoct something that will be of interest to all (it also makes it more interesting to us as we don't hear and read the same sort of material over and over again). The students will need to develop a project brief for their projects. Individual students with an interest in a particular project will also need to convince 3 others to join them. (They will have to develop their own proposal and market it to others). We will continue the sustainability theme - it must be a major part of the brief.

Some possible topics already proposed by the students include:
- Channel deepening in Port Philip Bay
- An outdoor recreation centre for RMIT
- Greening an RMIT building
- Greening a shopping centre
- Design a sports stadium

Particular skills for development in second semester include:
- Career development – where am I going?
- Computing – AutoCAD and, Excel
- Library skills, to support research skills
- Time management, group management and project management
- Sketching

In 2nd Semester we have the opportunity to undertake a small action research project ti study to student engagement in problem-based learning. Why do some students really engage and others don't? And what should we do to enable everyone to engage? Action research encourages the researcher to engage as part of the system, as opposed to traditional research that sees the researcher as the objective observer, separate from the system. We are keen to encourage students to take an action research approach to their own learning and career development.

Conclusions – where to from here?

We have developed a course that attempts to engage students in what it means to do sustainable engineering. We have developed a scaffolded approach that makes sure that all phases of the project life cycle are competently performed:
- Planning the project, deciding on tasks to be completed and time required
- Researching and defining the problem – what is really required?
- Generating alternatives and selection criteria
- Analysing the alternatives against the criteria using a sustainability framework
- Choosing a preferred alternative and making a recommendation
- Documenting the process

It is clear that there needs to be a more direct link between the lecture and the tutorials, and we need to make the lectures more engaging. One set of assessments might help so that students demonstrate transfer of lecture concepts into project practice.

We also need to engage all staff of 1st year in the development and implementation of this course. There is a lack of engagement by other civil staff. The environmental staff are interested and enthusiastic but they mostly don't teach into it.

There needs to be stronger links between this course and the other courses in 1st year, eg Statics. Stronger links between semester 1 and 2 are being developed as well as links to the rest of the program (how do the capabilities evolve through 2nd, 3rd and 4th year?).

Developing sustainable engineers continues to be a challenge!

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Biographies

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