A work integrated learning approach to teaching Water Resources Engineering

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Structured abstract

BACKGROUND
Traditional engineering courses usually focus on curriculum built around a fairly narrow engineering science context. This traditional approach to engineering education often fits comfortably with many students, who have built their skills around solving problems, which have been constructed around the solution of constrained engineering equations. Many engineering students quickly learn that achieving high marks in engineering course work is often all about getting the 'correct answer' to a solution method which has been spelt out in lectures by the teacher. In contrast, the sustainable management of water resources in Australian urban communities involves the integration of a broad range of issues covering social, environmental, economic and engineering aspects. Facilitating student learning around this type of engineering topic requires an innovative approach to curriculum and assessment design which places far more emphasis on these integrated issues. By developing engineering curriculum around a work integrated learning approach, students can be more easily motivated to develop their knowledge and understanding by applying ideas, concepts and theory to a 'real world' scenario.

PURPOSE
This paper describes the critical review and development of a water resource engineering course, which uses a work integrated learning approach.

DESIGN/METHOD
This paper describes a critical review of the development of the water resources engineering structure and highlights the way in which it has been designed to engage and motivate students to learn about the broad social, environmental, economic and engineering issues facing the development of urban water resources. Constructive alignment has been shown by Biggs and Tang (2007) as being an important way of focussing on "what and how students are to learn, rather than on what topics the teacher is to teach". The project described provides an innovative approach to alignment between the curriculum, assessment and resources within a traditional engineering program.

RESULTS
The paper shows that students are better able to engage with the complex issues facing water resource management in urban environments through the use of a work place based project. Engineering students are also more motivated to learn about these complex issues when they see how this relates to their proposed work environment. The curriculum is closely aligned to the assessment items which provide a balance between summative and formative assessment, through the use of milestones, final project report, project file and seminar.

CONCLUSIONS
The paper describes the application of a project-based approach to learning, where students are asked to develop a conceptual design for water and sewerage services in a proposed urban development. Although some resources are provided to students at the beginning of the project, others are provided as the project unfolds, which aims to mimic the development of a project within the workplace.

KEYWORDS
Work integrated learning, sustainable water management, conceptual design, constructive alignment.

Introduction

Traditional engineering courses usually focus on curriculum built around a fairly narrow engineering science context. This traditional approach to engineering education often fits comfortably with many students, who have built their skills around solving problems, which have been constructed around the solution of constrained engineering equations. Many engineering students quickly learn that achieving high marks in engineering course work is often all about getting the ‘correct answer’ to a solution method which has been spelt out in lectures by the teacher. In contrast, the sustainable management of water resources in Australian urban communities involves the integration of a broad range of issues covering social, environmental, economic and engineering aspects. Facilitating student learning around this type of engineering topic requires an innovative approach to curriculum and assessment design which places far more emphasis on these integrated issues.

Engineering students generally place a great deal of emphasis on tasks that they see are directly related to engineering practice. This is partly because students usually see their undergraduate engineering education in terms of vocational training towards a professional career in engineering. By developing engineering curriculum around a work integrated learning approach, students can be more easily motivated to develop their knowledge and understanding by applying ideas, concepts and theory to a ‘real world’ scenario. Patrick *et al.* (2008) also note the importance of this workplace based learning, as it allows students to gain a cultural awareness of the engineering discipline.

This paper describes the development of a water resource engineering course, which uses a work integrated learning approach. The cohort of students undertaking the course is currently enrolled in either the third or fourth year of the four year Bachelor of Engineering degree. The course, which is an elective course, is designed to prepare students for a professional team-working environment by investigating a current water resource issue. It is built around a project which has been structured so that students are better able to appreciate the way in which theory and practice combine to make them more ‘work ready’. This is noted by Patrick *et al.* (2008) as an important driver for work integrated learning within undergraduate programs. Students are also introduced to the conceptual design process for a piece of water and environmental infrastructure. The project-based approach adopted in this course has been identified by Mills and Treagust (2003) as being closer to professional reality and is more directed towards the application of knowledge, than the acquisition of knowledge.

This paper describes the structure of the water resources engineering project and highlights the way in which it has been designed to engage and motivate students to learn about the broad social, environmental, economic and engineering issues facing the development of urban water resources. Constructive alignment has been shown by Biggs and Tang (2007) as being an important way of focussing on “what and how students are to learn, rather than on what topics the teacher is to teach”. The project described provides an innovative approach to alignment between the curriculum, assessment and resources within a traditional engineering program.

The Water Resources Engineering project

The water resources engineering project described in this paper covers the development and application of a ‘real world’ engineering scenario. In this scenario, the students are employed by an engineering company which has been asked to investigate different options to improve the sustainability of supplying water and sewerage services within a proposed urban development. With this in mind, the developer would like to develop a showcase urban development of sustainable water management. The students are initially presented with a brief from the property developer, which states that the engineering company is to:

- Identify sustainable water management strategies for the proposed development;
- Identify the objectives of these water management strategies;

- Identify any environmental impacts resulting from these strategies, and any mitigation measures that may be required; and
- Provide a preliminary sizing of the infrastructure required with associated costs.

Motivating and inspiring students to learn

Most students are familiar with many of the social and environmental issues related to this project, as the sustainability of urban water resources resulting from potential climate change is a popular topic in the modern media. However, they are unfamiliar with ways in which they might address these issues from an engineering perspective. The project-based approach adopted allows students to take theoretical engineering concepts that have been introduced in other courses and apply them to design a system which satisfies the multiple constraints imposed in the 'real world'. Kestell (2008) have identified that this practical focus on "vocational problem-based learning" provides an excellent way of raising the profile of sustainability in engineering education. This is supported by the following student response from the course evaluation; *"The use of other examination methods as opposed to a final exam is a good idea, more like industry"* (Student Course Evaluation Feedback).

Students are asked to organise a small team from within their peers undertaking the course, to work on this collaborative team-based project. This may not represent the 'real world' work environment, where colleagues are often allocated independently by a supervisor to undertake project specific tasks. However, the team-based approach allows students to undertake their learning within a supportive collegial environment, taking advantage of the student's already developed peer support network. Students are also better able to investigate more complex 'real world' design strategies by collaboratively working with their colleagues. The collaborative nature of the team-based approach, within a supportive collegial environment allows students to more easily synthesise ideas covering the broad social, economic and environmental constraints and develop engineering solutions which are better able to address these often conflicting issues. However, as the majority of the assessment is based on individual submissions, there is usually little incentive for individual students to "free ride" in a group, as this will limit their ability to present coherent arguments related to the project design.

The feedback provided to each team recognises that each student has a unique set of skills that they bring to the project. Teams must work together to deliver a project outcome, and so it is important that each member of the team collaborates effectively with the other team members. This collaboration is reinforced by allowing students to choose other team members from within their peers, as it provides a supportive team environment. In this way each member of the team is able to further develop their own skills, as well as supporting others within the team to also develop their skills. This is a fundamental aspect of the project structure, which allows teams to independently develop their design, whilst being supported with constructive feedback on all aspects of their work, including team dynamics.

The assessment criteria for the project file include a component related to the development of a quality assurance process. The structure of the weekly meetings, plus the assessment framework adopted supports and encourages students to work collaboratively with each other to ensure the quality of each other's input to the project. This helps students to build confidence in their own ability to critically evaluate the work of their peers. This is an essential skill required by all students, as it helps them to develop the ability to critically evaluate their own learning, which itself is a fundamental aspect of self-directed learning.

In this way, each of the project teams becomes a "formal co-operative learning group", which Smith *et al.* (2005) identify as providing a mechanism for improving individual performance by "students learning together". Students are linked to each other within the team, as their team's overall performance relies on all members participating. Smith *et al.* (2005) describe this as students having a shared understanding "…that they sink or swim together". The combination of this "vocational problem-based learning" approach plus "formal co-operative learning groups" allows students to develop a much broader range of engineering design and analysis skills than is possible from a traditional lecture-based format. They are also inspired to further develop their own learning as most students recognise the importance of developing broad engineering based skills as part of their engineering training.

Students are encouraged to consider ideas and issues beyond the minimum constraints that have been set as part of the project description. This motivates students to consider learning as an active process, in which they are able to direct their own learning, whilst still remaining within the structured framework of the project. Each team meets weekly with the teacher who takes the role of the supervising engineer and provides technical and management advice related to the milestone being undertaken and the overall project direction. The weekly meetings with each team also reinforce this 'self-directed' approach by providing a learning environment where students are encouraged to investigate issues within an environment that is less threatening than that adopted with traditional assignment based courses. The weekly meetings can facilitate the timely correction of any misunderstandings made by a team, without causing serious setback to the team's progress. Although there have been cases of team dysfunction due to a range of reasons, these issues have usually been mediated through the weekly meeting process.

Teams can also canvass ideas and approaches to their project from the teacher at these meetings, which they are then able to adopt as part of their analysis. The teacher can also proactively identify aspects of the team's activities that may need to be addressed by the team. *"Group meetings ... give group specific feedback and support rather than addressing the whole class at once"* and *"Meetings for the Milestones were very helpful, being able to receive feedback in person was good"* (Student Course Evaluation Feedback). By addressing issues identified at these team meetings, the teacher is also able to identify aspects that require further discussion within the more formal lecture environment.

By focussing the project around a 'real world' engineering scenario, the students are encouraged to structure their learning using the professional engineer as a role model. The students are encouraged to direct their activities towards issues that are driven by the nature of the project and the physical constraints imposed by the site. This is one of the most motivating and inspirational aspects of the adopted teaching process, as most students appreciate the importance of developing professionally relevant skills. Engineering students are better able to appreciate the relevance of theory when it is developed within the context of a practical engineering outcome.

The adopted approach can challenge many students who are used to teacher focussed learning. Therefore, the project is structured so that students are not 'thrown into the deep end', but are led through the design process. This is supplemented with clearly defined milestones, feedback on group progress and formal lectures on relevant theory. The approach adopted provides a balance between project-centred and lecture-centred learning.

Aligning the curriculum, assessment and resources

The sustainability of urban water resources is an important local and global issue that is currently challenging many Australian communities. Climate change has been identified as a constraint on urban water providers in meeting their current demand for potable water (Queensland Water Commission, 2010). This will also impact future economic growth in the region. The future growth in demand for potable water is expected to have a significant impact on the natural environment, and any damage to this environment is likely to reduce the liveability of the area.

The topic of urban water management is a critical issue for professional engineers of the twenty first century, as the development of sustainable management strategies for water resources in this dry continent often requires the development of technological solutions. The development of sustainable water management solutions is not just an exercise in applying technical theory, but must also consider the broader social, economic and political issues as well. Therefore, the curricula and resources for the water resources project are structured around developing the conceptual design for urban water infrastructure that meets these diverse constraints. In this way, the students are better able to appreciate the way in which these constraints affect the decisions made throughout the various phases of the design process.

After successfully completing this course students should have been able to meet the following learning objectives:

- Describe the design and management of the various components of urban water resources including water supply, wastewater and stormwater systems;
- Undertake appropriate analysis of both potable water supply and residential wastewater systems, as part of the design of urban water resource systems;
- Evaluate the impact of a range of issues including economic, environmental, social, political, ethical, health and safety, constructability, and sustainability on the engineering design and management of urban water resource systems; and
- Communicate the outcomes of an engineering project related to the design and management of urban water resource systems in both a written and oral format.

The project has been structured so that students are first introduced to a broad open-ended scenario, highlighting the complex social and environmental issues faced when sustainably managing water resources in Australia. They are then asked to identify solutions, and investigate the issues to be addressed in designing a sustainable system. Each week, the focus is narrowed so that they are directed towards a specific system that can be designed using an appropriate level of engineering analysis. In this way, students are introduced to the ‘big picture’ of sustainable resource management whilst being nurtured through the development of an appropriate solution, without applying either simplistic technical analyses or complex ‘black-box’ engineering solutions. They are then more able to appreciate the open-ended nature of design, without adopting the ‘sink or swim’ approach common to many project-based approaches to learning. This approach supports the hierarchical structure of engineering knowledge (Mills and Treagust, 2003), where students need to build their knowledge on the foundations of other engineering knowledge.

The project is supported with weekly lectures covering various aspects of the project, timed to match the sequence of issues raised. Each team is encouraged to attend a weekly 20 minute meeting to discuss the status of their project, plus undertake six (6) milestone assessment items, in which the teams provide details covering a specific aspect of their project. These milestones are assessed by the teacher, who provides written feedback to the design team on aspects of their investigations, especially identifying issues that need to be more fully addressed. The milestones are introduced progressively through the semester as the focus of the project is narrowed towards the specific system being designed, with each milestone building on the work previously undertaken. Students are not overwhelmed by the scope of the project at the beginning, and are supported through each stage of the project.

Although the milestones form part of the summative assessment, with each milestone counting as 2.5% towards the final mark for the course, the feedback provided plays a far more important role as part of the formative assessment. The feedback allows each team to direct their efforts towards those aspects that will improve their overall design. The combination of summative and formative assessment both influences and improves student learning, which are the two essential elements of assessment described by Norton (2009).

Moni *et al.* (2008) describe the implementation of a co-operative assessment task for pharmacology and science students, where many students identified that allocating one mark to the whole group was unfair. However, they noted that they valued working in groups where the assessment was not summative. The continual feedback provided throughout the project actively encourages students to take ownership of their learning as it is designed to provide guidance rather than explicit error identification. By actively incorporating this feedback into their design they are then better able to prepare the report and seminar which carry the major component of marks for the course.

Where appropriate, each team is encouraged to investigate a broader range of issues than the minimum that is required to complete the design. Ideas initiated by students within each team are positively supported and ideas for other aspects that could be considered are suggested. Positive reinforcement of ideas initiated by students has been specifically undertaken in recognition of the importance of developing students as individuals. It encourages students to take ownership of their learning by respecting their input as a valuable contribution towards the final project outcome. However, it is also important to identify analytical errors that have been made, especially in terms of applying theoretical concepts. The assessment criteria for each milestone put equal weighting on the identification of important issues and on the accuracy of the analysis that has been undertaken.

Students generally develop their learning strategies based on the assessment defined as part of any unit of study. Al Kadri *et al.* (2011) note "...that assessment is one of the most important factors affecting students' approaches to learning". Scouller and Prosser (1994) also identify that assessment is "...possibly the single most potent influence on student learning...". So that the assessment helps define the 'Learning Paradigm', described by Barr and Tagg (1995) as allowing "...students to discover and construct knowledge for themselves...".

The assessment includes milestone reports (15%), an individual project report (50%), an individual project file (10%), plus a team seminar (25%) outlining the outcomes of their study. The individual project file must include some form of team-based quality assurance process, which must be described in a short summary section to the project file. In this way the students are able to reap the benefits of a team-based work environment to support their learning without the negative issues related to the 'fairness' of assigning a common mark to all members of the team. It also removes the need to impose an artificial weighting for different team members, based on the perceived 'contribution' provided by individuals as part of a team-based assessment mark using methods such as that described by Nepal (2012).

The main focus of the course assessment is based around communicating the outcome of the design process that has been adopted. The style of communication adopted in each assessment item is different, because the audience for each is different. Within the context of the 'real world' scenario adopted in this project, the final report and seminar are directed at the project client, whilst the milestone reports and project file are directed at the design supervisor. Playing the role of the professional engineer helps students to better appreciate the difference in these communication styles and where each is appropriate. The resulting assessment is designed to be 'authentic', as defined by Svinicki (2005), based on activities that replicate the way a professional will perform within their professional environment.

Students are provided with a set of assessment criteria at the beginning of the project for all assessment items. As an example, the assessment criteria and weighting for the project report assessment item include the following:

- Report structure (20%);
- Grammar and spelling (20%);
- Appropriate use of references (10%)
- Assessment of project constraints (10%);
- Assessment of Engineering and Environmental issues (20%); and
- Accuracy of analysis (20%).

Each of the assessment criteria unambiguously identifies each of the criteria to be assessed, and defines through a rubric the nature of work that constitutes each level of attainment. The assessment criteria recognise the importance of following a logically structured design process based on reasoned investigation and analysis, and not just about getting the 'correct answer'. They also recognise that "students deserve to be graded on the basis of the quality of their work alone," and that they "…deserve to know how judgements will be made as to the quality of their work", which are the two ideals of criteria-based assessment, as described by Sadler (2005).

However, the seminar presentation focuses on the communication of the design outcomes to the client in the form of a client meeting. Although the students have worked as a team in the project, the majority of the assessment is based on individual performance for each of the assessment items. For the seminar or client briefing, only 20% of the assessment is based on the team's performance. Rather, the majority of the assessment focuses on the way in which individual students have communicated the project outcomes to the client. This overcomes the problems related to students who "free ride" in groups. The assessment criteria adopted for the seminar include the following:

- Presentation structure (Team 20%);
- Answers to questions (Individual 20%);
- Use of visual aids (Individual 20%);
- Presentation style (Individual 20%); and
- Discussion of topic (Individual 20%).

A report template is provided to all students showing all of the appropriate formatting to be adopted in the final design report. This allows students to focus their efforts towards developing the content of the document. It also provides guidance on the appropriate way to structure information within the final document. Guidance is provided to the students on issues to consider when preparing the design report, and when preparing the project file.

These resource materials have been developed to identify the differences in the communication styles required for each of the assessment items, including the milestones, the final project report, project file and project seminar. A checklist for the final report is provided to help students ensure that the various aspects of appropriate communication style have been addressed. These resources are provided electronically and can be downloaded from the course web site. The resource material is also supplemented with lectures covering different communication strategies to adopt in each form of communication.

Conclusions

This paper discusses the application of a work integrated learning approach to teaching water resources engineering. The paper has shown that students are better able to engage with the complex issues facing water resource management in urban environments through the use of a work place based project. Engineering students are also more motivated to learn about these complex issues when they see how this relates to their proposed work environment.

The paper describes the application of a project-based approach to learning, where students are asked to develop a conceptual design for water and sewerage services in a proposed urban development. The curriculum is based around the delivery of lectures and small team meetings to support the 'team-based project'. This is closely aligned to the assessment items which provide a balance between summative and formative assessment, through the use of milestones, final project report, project file and seminar. Although some resources are provided to students at the beginning of the project, others are provided as the project unfolds, which aims to mimic the development of a project within the workplace.

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