Fostering project management competencies in undergraduate engineering: An exploration of the use of management-educated tutors as coaches in problem-based learning

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STRUCTURED ABSTRACT

CONTEXT
Problem-based learning (PBL) helps engineering graduates develop the competencies needed in order to engage effectively with complex and uncertain workplace demands. PBL's effectiveness, however, also depends on students having the ability to manage themselves and to work collaboratively. As these professional competencies are not typically the focus of undergraduate engineering programmes, students tend to complete problem-based project work through their own initiatives without the skills relevant to project completion. On the other hand, project management competencies are commonly explicated and core in business and management disciplines.

PURPOSE
This paper reports on our project which addresses the research question: *What is the impact of utilising a management-educated demonstrator to work with engineering students on their learning and development of project management competencies?*

APPROACH
Our project intervention required students in a fourth-year advanced engineering problem-based course to regularly report their planning and project progress to a graduate management tutor (demonstrator manager). A third of the course marks was awarded by the tutor who provided business-informed coaching as feedback during each report planning session. Multiple forms of data were collected – pre-and post-course surveys, student focus group interviews, lecturer and tutor interviews and student formative and summative grades.

RESULTS
The findings highlighted that:
(1) Students did gain a better understanding of key aspects of project management;
(2) Students were generally supportive of the technique, but wanted more "introduction", exposing their naivete where grading on management was concerned;
(3) The approach could foster more Engineering-Management collaboration at a university;
(4) The approach supports the accreditation goal of developing engineering graduates' professional competencies related to management skills.

CONCLUSIONS
Given the multiple and complex challenges facing 21st-century society, engineering employers are increasingly seeking graduates who are both technical experts in their field and able to work with experts from other fields, including business and management. Our project contributes understandings on how interdisciplinary initiatives can develop such professional competencies that are important for engineering graduate work-readiness.

KEYWORDS
Interdisciplinary study, project management, problem-based learning

Introduction

As a result of globalisation, advances in science and technology, and the challenges of sustainability, engineers are being asked to provide solutions in contexts that are increasingly complex, uncertain and frequently classed as "wicked problems" (Weber, Lach & Steel, 2017). Engineering students therefore need to develop a wide range of complex skills and competencies that include an ability to engage with real-world problems as engineering professionals. In addition to content (technical) knowledge, engineering students are increasingly expected to graduate with strong analytical skills, practical ingenuity, creativity, good written and oral communication skills (Chung, 2011; Male, 2010; Paretti, McNair, & Leydens, 2012), and critical ethical/moral agency (Campbell & Zegwaard, 2015). Additionally, in order to meet the engineering graduate attributes and professional competencies detailed in the Washington Accord, students need to develop a range of technical and extra-technical skills (International Engineering Alliance, 2017). The Accord lists 12 graduate attributes, including problem analysis, design and development of solutions, investigation, engineer and society, ethics, individual and teamwork, communication, project management and lifelong learning.

Project-based learning (PBL) has been shown to develop the range of competencies and attributes engineering graduates require to face complex and uncertain workplace demands (Kolmos & de Graaff, 2014) and is being systematically introduced at our university's School of Engineering. However, in order to complete problem-based tasks successfully, students need to employ engineering and project management knowledge and skills. As these management competencies are not typically the focus of undergraduate engineering programmes, students tend to complete problem-based project work through their own initiatives without any training in the skills relevant to project completion. Moreover, these competencies are very difficult to assess and engineering lecturers typically have neither the time nor the expertise required to use and teach these competencies. This lack of support can compromises PBL and learning outcomes, and is driving engineering educators and programmes to seek interdisciplinary initiatives to solve this gap.

This paper reports on the findings from a qualitative study investigating the potential of fostering students' project management competencies through working with a management-educated tutor/coach in an advanced PBL engineering course context. This aim is underpinned by the research question: *What is the impact of utilising a management-educated demonstrator to work with engineering students on their learning and development of project management competencies?*

The findings will offer useful practice ideas for other lecturers/ programme designers and course leaders involved in PBL across the university/similar tertiary contexts.

Research Context and Design

The Course

This study is based at the University of Waikato's School of Engineering. The Mechatronics paper/course is offered to final year electronic engineering (EE) students. It is designed for advanced students to integrate their learning of concepts from three years of coursework and to apply them in a series of three projects. Each project increases in complexity and builds on the learning from earlier projects. The course is entirely problem/project-based. Students work mostly independently on their projects and are allocated lab workspaces and equipment simulating environments in real-world engineering workplaces/industries. Classes in the paper are scheduled for two hours each day of the week for an entire semester but students have the flexibility of accessing their workspaces and equipment in the laboratory (lab) whenever they need them, and most do. The course typically has an enrolment of between eight and 16 students each year. Students are required at various stages to program microcontrollers, design and build small interface circuits, process sensor inputs, drive actuators, transmit or receive data, parse data packets, etc.

Traditionally the course is convened by a single lecturer who offers technical assistance through lectures supported by lab work to facilitate students' developing and successful construction of their projects. The lectures highlight the theoretical understanding and technical ideas students will need to apply in their projects. These would be reinforced by the lecturer running short mini-lectures during labs as and when needed to support students persistently facing an issue in their project work. Given that the lecturer is expert in the area and had been teaching the course for 10 years, he is able to pick up students' assumptions and misconceptions quickly and address these early in the course to guide

their thinking. The lecturer felt however that this may not be benefitting students' learning of important non-technical skills (i.e., planning, self-management and problem-solving skills) so that, for example, students had difficulty planning milestones and articulating their thinking. As Glaser (1987) pointed out, experts differ from novice learners in terms of "knowing what one knows and doesn't know, planning ahead, efficiently apportioning one's time and attentional resources, and monitoring and editing one's efforts to solve a problem" (p. 13). The lecturer was thus keen to investigate strategies that would enhance students becoming aware of, and articulating, their own planning, managing and problem-solving aspects of their project. These included trialling a new assessment structure in the course that included a component requiring students to report on their planning and progress to graduate tutors from a management background rather than technical, as occurs in industry.

An earlier pilot trial was conducted last year. For pragmatic reasons due to staffing availability, the management tutor role was taken up by an honours science student with a previous commerce degree giving her just a slight advantage in terms of understanding of the technical terms used in the course. Generally however, the lecturer, students and the tutor herself reported the fact that the tutor did not know much about the technical details of their projects to be key to students' learning and developing management competencies (see Scott, Khoo, Cree, & Seshadri, 2017). Students were forced to communicate their ideas in layman terms and to develop a detailed plan for troubleshooting and achieving their next milestone. Overall, students strongly recommended that the trial be continued. In this year's trial, the lecturer was keen to see if similar findings would be obtained with management tutors from non-science backgrounds. We anticipated the findings to be similar in this study and seek to highlight the benefits and strategies for working productively across engineering – management disciplines (including students' suggestions for improving the intervention).

The Intervention

Our research was based in a fourth-year advanced engineering problem-based course. It required students, who were working on a series of cumulative individual project-based work, to report regularly on the planning of their project work and progress to a graduate management tutor working in the role of a demonstrator manager. This is akin to how students will be required to work as professional engineers on real-life work projects that involve interactions with business managers and potential clients from diverse backgrounds; some with an understanding of engineering principles and some, without. The lecturer continued to offer technical assistance to students through lectures and lab work but organisational assistance and reporting was provided by the demonstrator manager. One-third of the marks for the paper was awarded by the demonstrator manager based on her evaluation of students' planning and project management, and the timeliness and comprehensibility of their reports. Key to the process was the fact that the tutor did not know much about the technical details of the projects, forcing the students to plan their work, explain milestones in consultation with her, and explain their progress to an "outsider". Students reported their progress to the tutor on a weekly basis. The tutor would drop in several times a week or every other week during students' lab hours. In these reporting sessions, students meet individually with the tutor to provide a quick update of their work, go through issues they have encountered and provide an outline/plan for troubleshooting and achieving their next milestone. Students could also email their progress if they missed seeing the tutor. The approach draws from Packard's (1985) *Management By Walking Around*.

Data Collection

Multiple forms of data were collected – lecturer and management tutor interviews, students' progress achievement in each project, tutor's feedback to students, student focus group interview, and student pre- and post-survey – to address the research questions and serve as a form of triangulation. The survey was conducted online via Google Forms and was collated and analysed using Microsoft Excel software while the interview data were thematically analysed to identify emerging themes (Braun & Clarke, 2006). Each form of data was analysed separately and then triangulated to address the research aim. This article focuses on students' perspectives and their feedback on the intervention.

Participants

Sixteen students enrolled in the course consented to participating in the study. All students responded to the pre-course survey while 13 students responded to the post-course survey. Of these, nine students attended the focus group interview. The study received ethical approval from the University's Human Ethics Committee and all participants participated in the study on a voluntary basis.

Findings

We report the benefits of the intervention for learning as well as suggestions for improving the intervention based on findings from the student surveys, which are then corroborated with representative interview quotes.

Benefits to Learning

Student perception of learning

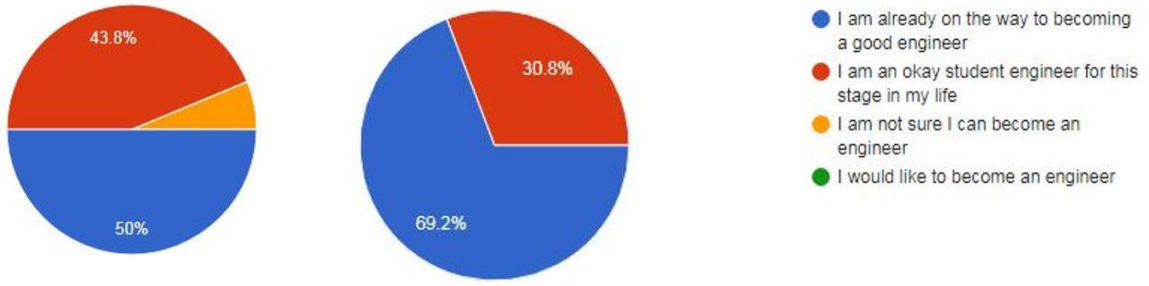

Figure 1: Pre- and post-course survey of student perception of their development as engineers

A comparison between students' perception of their becoming a good engineer revealed that about 70% of students at the end of the course reported they perceived themselves to be on their way to becoming a good engineer in comparison to 50% of students who thought the same at the beginning of the course (see Figure 1).

When asked if they have become better at applying project management activities/strategies after attending the course, 69.2% responded positively. Reasons given for this in the open-ended question ranged from those learning self- and/or project management as a new skill (e.g., by setting milestones or communicating with the demonstrator manager) to those who are already adept at it but refining aspects of their skills:

> *I am able to list out the task related to the project and assigning a deadline for each task. So that I can finish the project on time.*
>
> *I have been working hard on achieving small goals in the project and taking it one step at a time.*
>
> *My methodologies haven't changed I have just learned to articulate more*

When asked how helpful their regular reporting/discussing their project's progress with the demonstrator manager was, 69.3% of students responded the experience to be 'very helpful', 'helpful' and 'somewhat helpful' (see Figure 2).

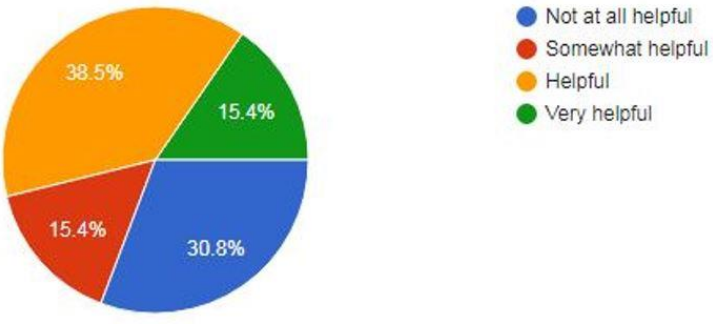

Figure 2: Value of regular reporting to the demonstrator manager

Students' reasons for this trend touched on the role of the demonstrator manager in monitoring and reminding them to maintain progress in their project work:

> *It was good to have someone monitoring your progress, so you didn't fall behind and it helped break down the work and allow time for other papers*
>
> *It prompted me to review my own project milestones/timeline*
>
> *It made me better recognize what steps I had to complete and how long I had to do them.*

Nevertheless, over 30% of students appeared to derive no benefit (Figure 2) and the same tranche said that the feedback from the tutor was not helpful (Figure 3). It is our perception that this attitude expressed by this portion of students arose because they were already sufficiently good, particularly at self-management, that they were more able than the management demonstrator. The authors found considerable difficulty recruiting management demonstrators of sufficient ability in our studies. (It is similar with technical tutors in demanding papers at our university, although this is not relevant here.)

Similarly, 69.3% of students reported the feedback they had received from the demonstrator manager to be 'very helpful', 'helpful' and 'somewhat helpful' (see Figure 3) in keeping them on track.

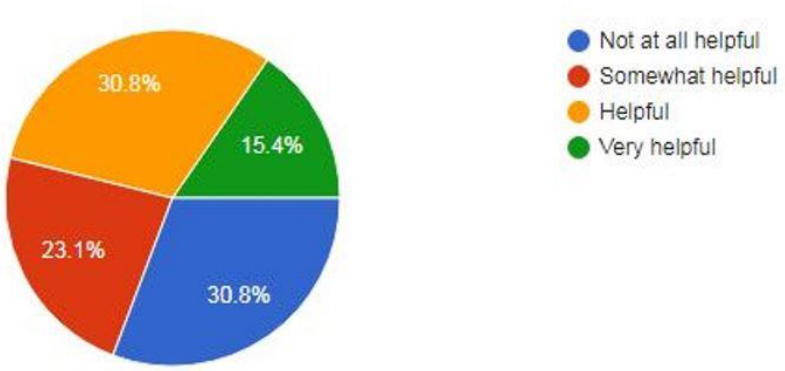

Figure 3: Value of feedback received from the demonstrator manager

Further, when asked if they had changed the way they manage their project work as a result of the demonstrator manager's feedback, 69.2% reported 'yes'. Reasons students offered for this response in the open-ended question included:

> *Emailing more and actually doing little bits each day/week so that I had something to show/update her*
>
> *Made sure to keep log books and Gantt charts*
>
> *Formalised reporting and planning*
>
> *I am[aim] to create a project schedule.*

Students were also asked to rate how competent they believed they were on a range of 17 non-technical competencies in the pre- and post-course survey based on a five-point Likert scale. Student perceptions of their competency in four of these 17, 'scoping their project', 'communicating clearly by written means', 'communicating clearly by oral means', and 'setting milestones', increased as a result of the intervention. In support of the survey data on shifts in students' perceived competencies related to project management, students in the focus group highlighted that a key learning from the experience was learning to communicate their ideas clearly to a non-technical audience:

An important thing about being an engineer now is being able to communicate your ideas to people in society who doesn't necessarily know what is going on. So in having to learn how to explain what we are doing to someone who doesn't understand it, that is a really important part of being an engineer in today's society. That is the biggest takeaway from this management component.

Suggestions for improvements

Some recommendations offered by students to enhance their learning experience include ensuring the demonstrator manager has some industry (engineering) experience, clarifying expectations for the management component of the assessment, communicating these clearly, and ensuring clarity around the marking scheme. For example, in the open-ended survey questions, students reported:

Use supervisors with industry experience

Have someone that knows a bit about electronics or engineering

Have a more clear cut outline for what we need to provide for the management side, there was a bit of a mix up for the first project and I didn't feel I knew what I needed to show until the last project

Clearly outline expectations of progress updates at the start of the course, and potentially provide teaching content on how to do so. For example, on creating a schedule, keeping to it, and compartmentalising aspects of a project. As mentioned previously, a manager with some understanding of the projects would be desirable. While there is the potential that a manager will have no idea how your project works in industry, I feel like this is too unrealistic of an assumption to make in the engineering field.

In the focus group, students affirmed these points, they reiterated the importance of establishing expectations about the project management component of the course including providing a lecture and some resources regarding its importance:

Setting up what we will be marked on right at the start. Keeping the consistency right through all the time. Also right at the start have a lecture on the sorts of skills we need to apply in relation to this project management aspect to make sure we are all on the same page and we know what is expected of us.

Some papers on project management to introduce the general idea of project management, as it is a skill we are aiming to develop so we know what we are doing and direction

Clarity around the marking scheme, or a more objective and transparent marking scheme, as well as formative feedback on students' learning, were other key ideas for improving the intervention:

If we had been told at the start of the project, in this component of the mark, you will be marked on this, this, and this, we can aim to make sure we meet certain standards for each of those criteria but we didn't learn what those criteria were [until later]

Also some feedback as well [would be good] during the project- how well we are actually scoring in terms of the marks. Lecturer is doing a technical analysis of how well we are understanding and he's updating the marks [for the technical component of the course] on Moodle every now so we have an estimate of how well we are doing and where we stand. In terms of [tutor]'s marks we don't know how we are doing until we get all the marks back. She could tell us we are sitting at a 6[out of 10marks] and what else we need to do to improve [along the way].

Several students also thought the one third marks allocated for the intervention in the course was too high:

Being able to explain something non-technically is not worth a third of the paper…it can be lowered to 15 or 20%.

Overall, students agreed the intervention should be continued as it offered a different learning experience unlike in other courses but added for their suggestions for improvements to be considered.

Yes should be continued as it has something different unlike other papers

Discussion and Conclusion

The project sought to make available both disciplinary technical knowledge support (i.e., from the course lecturer) and professional (non-technical) knowledge and support for learning (i.e., from the graduate management tutor/demonstrator manager in this project) to help final year engineering students integrate conceptual and professional competencies in their PBL work. The findings indicate that students gained a better understanding of key aspects of project management because they had to report their progress regularly to the manager (e.g. scoping their project, communication, setting milestones). All students were supportive of the intervention and highlighted the opportunity to communicate in non-technical language to the demonstrator manager to be an asset. They raised the need however to review the way the intervention was introduced and set up in the course, the marking scheme associated with it, and more informal formative feedback on their learning and performance as useful suggestions for enhancing the course and the value of the intervention. This alludes to the need to attend to the 'initial conditions' – particularly when they are related to grades – for interdisciplinary collaboration. That is, establishing protocols for how the interdisciplinary work will be accomplished is important - how graduate management tutors will work with the undergraduate engineering students and be supported in this work. In our experience finding suitable and available graduate management tutors for the project was a practical issue. This will need to be addressed in future work and as a consideration for others interested to trial this initiative. Having located suitable management tutors, an initial workshop could be held at the beginning of the course to ensure management and engineering students are aware of project management terminologies and the tools and ways of working that will be used in the course. These findings can inform more robust engineering-management collaboration as a strategy for ensuring engineering students develop broader competencies aligned with the graduate attributes identified in the Washington Accord and university to ensure they can confidently take their place at the cutting edge of the global professional arena.

Although this small study may not generalise to other contexts, we hoped that the insights gained might help inform other educators interested in pursuing the assessment innovation and assist them in considering ways of implementing it in their practice. In future research, we look to extend this study with the aim of better characterising what is required in the "demonstrator manager" role, and also by testing a refined version in larger classes.

References

Scott, J. B., Khoo, E.., Cree, M. J, & Seshadri, S. (2017). Assessment of Self-Management Skills in a Project-Based Learning Paper. In Proceedings of the *28th Annual Conference of the Australasian Association for Engineering Education*. Sydney, Australia: Engineers Australia. Available at https://hdl.handle.net/10289/11591

Belland, B. R., Glazewski, K. D. & Richardson, J. C. (2011). Problem-based learning and argumentation. *Instructional Science: An International Journal of the Learning Sciences, 39*(5), 667-694.

Kolmos, A., & de Graaff, E. (2014). Problem-based and project-based learning in engineering education: Merging models. In A. Johri & B. Olds, (Eds), *Cambridge handbook of engineering education research* (pp. 141–160). Cambridge, UK: Cambridge University Press.

Weber, E. P., Lach, D. & Steel, B. S. (Eds.). (2017). *New strategies for wicked problems: Science and solutions in the 21st century.* Corvallis, OR: Oregon State University Press.

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