Implementing MUSIC Components to Enrich Engineering Capstone Projects: The Students' Perspective and the Instructors' Standpoint

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SESSION C1: Integration of theory and practice in the learning and teaching process

CONTEXT Effective teaching involves engaging students in ways that are appropriate to the development of deep approaches to study. Deep approaches are encouraged by creating opportunities to a responsible choice of study, by demonstrating meaning and relevance of content to students, by implementing teaching and assessment methods capable of motivating active and long-term engagement, clearly stated expectations, interest in the subject, and educational settings. Capstone/engineering projects, which explore problem-based learning (PBL) approaches, provide an opportunity for students to practice applying their knowledge and workplace skills while they engage in a collaborative environment. PBL could be effective if teaching and learning methods were meticulously set in terms of course preparation, scenario design, implementation, and assessment.

PURPOSE In this article, we investigate how instructional elements of problem-based learning can affect students' engagement in capstone engineering courses and help them to feel prepared to work effectively in their profession.

APPROACH The effect of the five components of the MUSIC Model: eMpowerment, Usefulness, Success, Interest, and Caring, on students' motivation and their ability in problem solving, critical thinking, coordinating with others, and cognitive flexibility, was measured in relation to students, their teammates and instructors. We used a two-phase mixed method approach including both quantitative and qualitative assessments. In the quantitative phase, a group of students in Engineering/Capstone Project from civil engineering department completed a questionnaire with a set of questions related to the MUSIC components and their responses were analysed in a qualitative phase.

RESULTS Results of two-phase mixed methods approach revealed that if motivating opportunities are used properly, they can foster students' positive perceptions of the MUSIC components, and avoid frustration and the lack of motivation. These motivating opportunities are important because they can help instructors to plan and implement PBL instructions more effectively and improve student's engagement.

CONCLUSIONS The qualitative data analysis indicated that three categories of PBL were relevant to students' motivation: project design, group experience, and project advisor. The findings in this article can improve students' success beliefs by making course expectations clear, assessing students at an appropriate level, and providing continuous feedback.

KEYWORDS MUSIC components, Capstone Projects, Problem-based Learning.

Background

In a majority of engineering subjects, educators have shifted away from factual (didactic) teaching towards contextual teaching in the form of problem-based learning (PBL) (Epstein, 2004). The aim of PBL is to acquire the ability to 'learn to learn' and construct new knowledge, rather than what is actually learned or taught (Healey, 2005). Various studies highlighted that PBL also promotes deep learning through greater understanding of concepts and development of skills, while fostering student participation and motivation, which can cultivate lifelong learning (Epstein, 2004; Pawson et al., 2006; Ribeiro, 2011). PBL can be interpreted as 'problem first learning' (Spencer & Jordan, 1999) in which instructors set a problem which defines what is to be learned. Curriculum, course or assignment contents are organised around problem scenarios, rather than subjects or topics (King, 2001). It demands from the learner the acquisitions of critical knowledge, problem-solving efficiency, self-directed learning strategies and team participation skills.

The PBL stimulates learning through the replication of challenges that students can encounter in life/career and requires them to determine appropriate learning resources. This can be achieved through curricula that promote students' general and scientific knowledge, integration of theory to practice, development of interpersonal, written and oral communication skills, students' critical and conceptual reasoning, the capacity to reflect on their own practices and learn from practical situations (Tynjälä, 1999), without extending the period of formal training (Ribeiro, 2011). If PBL is implemented poorly, there is a chance that the students may not identify the relevance of the learning materials to their future engineering career. This lack of understanding can be demotivating for students' learning (Kember et al., 2008) and teachers may be seen as the imparter of knowledge, as students merely reproduce and regurgitate said knowledge. This is known to lead to lower levels of effective learning. As a result, appropriate implementation is a key part of a successful PBL approach.

PBL involves not only educational and institutional changes, but it also demands individual changes from students and instructors. The implementation of PBL requires participation, planning, and cooperation of students and teachers. Implementation of this process is challenging as it requires students' and teachers' involvement and it is time consuming. The process of PBL brings a more complex and uncertain situation for a teacher than conventional lectures (Ribeiro, 2011). In PBL settings, teachers need to act as a co-learner, guide and facilitator. These multiple responsibilities demand preparation, planning, time and a good knowledge of the subject.

An important risk in PBL is related to the design of problems for students to solve. The problem should be real, complex, and multi-dimensional to allow students to work as a team, and well-designed in order to be solved in a specified time frame. However, the definition of such problems also makes students' learning more demanding, as they need to simultaneously allocate the time to learning other subjects. The problem should have clear outcomes and need to be well translated to the group of students. The teacher is responsible for forming groups to work on a problem and should assign each student specific roles in order to avoid barriers to participation. The teacher should also probe the students with questions which promote critical thinking. The effectiveness of PBL, however, could be compromised by poor group dynamics amongst students, in which case timely intervention from teachers' is a requirement to mitigate the issues.

As an engineer, students will face different problems in their professional life and they need to rely on their engineering judgement to solve and overcome challenges. As workplace, professionals, they are required to demonstrate their ability in problem solving, critical thinking, coordination with others, and cognitive flexibility. Capstone projects provide an opportunity for students to practice and improve their knowledge and workplace skills while they engage in a collaborative environment.

Jones et al. (2013) investigated how instructional elements of PBL can affect student's engagement in capstone engineering courses. They measured the effect of five components of the MUSIC Model: eMpowerment, Usefulness, Success, Interest, and Caring, on students' motivation. Instructor interaction is a motivation element and some students mentioned that they benefitted from their instructor's feedback since it reinforced the sense that they are supported, while other groups found confronting to obtain feedback from their advisors. This lack of feedback hindered students' success. They claimed that students can still be motivated even if all the MUSIC model components not reach high levels. This can be due to the fact that instruments used in this research were developed and validated by different researchers for various purposes.

MUSIC Components in Capstone Project

In this section, we discuss about the relationship between authors' teaching/supervisory method, and students' motivation and approaches to study. To support this, we completed a questionnaire from students in Engineering/Capstone Project at the University of Sydney and identified the key elements of our teaching methods based on the four lenses of Brookfield (1995). This unit of study (UoS) provides a great opportunity for students to conduct original investigation and research work. Students generally work in groups, although the planning and writing of the thesis is done individually. Working arrangements are informal, as are the relationships between the students and their supervisor. This unit can help students to improve critical thinking, problem solving skills, and decision making. Students learn to improve their ability to explore and formulate appropriate methods for investigating research questions. At the end of the unit, the students are expected to have in-depth knowledge of the area which most likely helps them to find their future job.

Based on Ramsden (2003), effective teaching involves engaging students in ways that are appropriate to the development of deep approaches, such as exercising responsible choice of study, demonstrating meaning and relevance of the content to students, teaching and assessment methods to motivate active and long-term engagement, clearly stated expectations, interest in the subject, and educational settings. In this light and similar to Jones et al. (2013), we tried to measure the effect of these five components (MUSIC Model): eMpowerment, Usefulness, Success, Interest, and Caring, on students' motivation. We measured these components in relation to students, their teammates and instructor. We used a two-phase mixed methods approach, comprising both quantitative and qualitative approaches. In the quantitative phase, the students completed a questionnaire with a set of questions related to the MUSIC components and their responses were analysed in the qualitative phase.

Currently, we are supervising 3 groups of undergraduates and two master thesis students. For undergraduate and post-graduate students, group sizes are comprised of three and one student per group, respectively. To learn about our students' motivation and approaches to learning and to reflect on our teaching philosophy, we selected students from each group, all of them in the final year of their civil engineering degree. Students are from different countries and levels (undergraduate/post graduate). Undergraduate students are from China (Students A–C), Malaysia (Student D), and Australia (E–G) while the postgraduate student is from Guatemala (Student H & I). The questionnaire was designed to determine students' motivational parameters and their approaches to learning during the final year project. Table 1 summarises items in the questionnaire. The first two questions of the motivational part focused on students' major (civil engineering, double degree, etc.) while the remaining questions attempted to discover students' motivation and approaches to learning in the unit of study. Students were notified that all aspects of the study, including results, will be strictly confidential and that they will not be identified in anything they write. Participation was also voluntary and participants were instructed to type their answers to each question prior to our weekly meetings and then to print it and bring it along to the class where a table at the back of class was assigned for collection of the questionnaire and Consent Forms.

Table 1: Targeted items in the questionnaire for the current study.

Motivation	Approaches to learning
How did you come to choose this course?	How did you determine the topic you selected?
Can you mention a unit of study that you really enjoyed in the course? Why did you enjoy it?	Can you please describe what you are doing in order to learn during this unit?
Are you interested in the context of this subject? What makes it interesting/not interesting for you?	What do you think influences you to learn like that in this subject?
Do you feel in control of your learning in this context? If not, what is your suggestion?	What would convince you to take a different approach?
Do you believe you can be successful in this subject?	What is the workload like in this subject?
Do you think the content/topics are (or will be) valuable to you?	How do you approach the assessments?
How do you think this subject can help you in your short-term/long-term goals?	Describe your group's dynamics?
	What would you change about the role of your advisor?

Discussion

By analysing the questionnaire responses, it was revealed that if motivating opportunities are used properly, they can foster students' positive perceptions of the MUSIC components; otherwise, they lead to students' frustration and a lack of motivation. For instance, we believe one element of collaborative learning that influenced participants' motivation is the students' freedom in the selection of their project. Time is another important parameter in designing successful courses. Some motivating opportunities are established prior to the start of the course, such as the student's freedom to choose their topic, group, or advisor. Therefore, it is important to investigate the parameters that move the course dynamic towards a professional engineering environment and to consider how these parameters vary with time. Three students noted that they had the opportunity to select a project based on their individual interest, whereas Student H chose the topic after consultation with his supervisor. Student D mentioned that: "this topic is selected by my teammate and we are both interested in the topic since it involves experiments". It appears that most of students selected topics that are tied to their career plan: "… to achieve good knowledge in that particular area", "… in the context of structural (engineering)", or "… to gain enough knowledge and (to) apply it to everyday situations". This is closely related to their motivation (i.e. personal interest or future job prospects, studying something more practical) for selecting their course in the first place, too. Students who do not believe the project matches the real-world practice or it does not meet their career goal expectations experienced motivation problems. It is critical to design the project in a way to interest students and to be useful. Since the sample size in this qualitative questionnaire was relatively small and all participants had the freedom to choose their project, the authors were not able to measure students' motivation level when the project topic was enforced without particular care for their individual or career interests.

Students' self-efficacy was measured by asking the students to reflect on their ability to organise and implement the actions needed to perform effectively during the project. This unit of study consists of two year-long engineering/capstone projects. To the authors' interest, all students strongly believed that they will be successful in their project even in the middle of the first semester. This may be due to the: students' interest, clearly stated expectations (guided journal which was provided during our first meeting), interactions with peers, or feedback received from their supervisors. This can show the link between motivation, interest and assessment. Good teaching implies engaging students in ways that are appropriate to the development of deep approaches. Research (Ramsden, 2003; Bandura, 1977) indicates that students with high self-efficacy adopt a deep rather than a surface approach that positively influences students' motivation and achievements. Having said that, the authors are planning the students to complete another questionnaire at the final stages of their project during second semester to understand how these motivational opportunities fluctuate throughout the unit. This is important because it can help the instructor to plan and implement educational methods more effectively and to improve students' engagement and success beliefs by making course expectations clear, assess the students at an appropriate level, and provide continuous feedback.

Using a mixed-methods research approach, Dunlap (2005) studied how self-efficacy during a problem-based learning (PBL) experience can help the students feel prepared and work effectively in their profession. The author examined 31 undergraduate university software engineering students during a 16-week capstone course prior to graduation. Results of this research showed that acquisition of skills is not enough to be competent in the subject and requires another element, i.e. students' self-efficiency, which is interpreted as students' individual level of confidence to perform effectively. This finding is particularly interesting to our project because it can help us to suggest specific instructional strategies to improve students' performance. Dunlap (2005) used guided journals to process data and to scale self-efficacy based on collaboration and reflection. Results showed that journal writing not only can foster understanding and enhance student's critical thinking and achievement, but also is an effective way to capture students' reflective practice, conceptual change, thinking, and learning. Changes in students' confidence was measured at three intervals: before, during, and after PBL experience. Dunlap's (2005) results showed that all students expressed a lack of self-efficacy prior to their PBL experience which was improved during the course, and replaced by confidence at the end when students started referring to themselves as software developers rather than students. The author also pointed out the importance of early and frequent opportunities for students to engage in PBL and work on professional practice. In this paper, Dunlap (200) claimed that student growth in self-efficacy was a result of participating in PBL since students were exposed to the PBL environment for the first time.

Based on our previous experience, students who collaboratively get involved in a research-intensive environment improve their critical thinking and hands-on skills. Working as a group provides various opportunities to motivate students. Some participants felt it empowered them regarding group's dynamics and work allocation: "my groupmate and I work together a lot and we learnt a lot through discussing and searching for information …"; or other highlighted that their group interaction was motivated through a friendly environment: "… everyone is very friendly and helpful, I like to work with them".

> Student E: We have been friends for years and have been in groups for many previous subjects so our group dynamic was fine.

As teachers, we try to develop a mentoring relationship with our students and develop their scholarship in the field. Students learn best through reflection, as it enables them to become reflective and collaborative thinkers who are also effective communicators. Through reflection, students are able to understand themselves more and then understand their learning better. As much, we arranged weekly meetings for students to reflect on their progress. Students present their approaches and discuss the outcomes in front of other groups. Meetings take almost one hour and thirty minutes. Each group is assigned about 20 minutes to discuss their findings/issues. Some of the students highlighted that weekly meetings with their supervisor and their peers help them to improve their learning process. Students B, D, and E noted that perhaps more one-to-one discussion sessions with their supervisor would help them to make sure they are on the right track;

Student E: Advisors did a good job. Only recommendation would have been to have more individual time with each group to focus on specific issues at hand.

Student H raised a concern about how the feedback from supervisor is provided: “I would like to have a better approach on how the feedback is given, and how they (supervisors) use their expertise to give us better ideas”. This is one important parameter to consider; consequently, we need to revise structure of our weekly meetings in order to shift towards a teaching style students are more accustomed to in an effort to help with their approaches to learning.

Conclusion

Capstone projects encourage the students to think and interact with the environment which is said to have a positive effect on their learning. It also motivates the students to research and learn contents as they encounter real life problems. Problem-based learning approach in capstone projects triggers students’ basic knowledge, skills, group interaction and self-learning abilities. In this project, we discussed the benefits and risks in the implementation of PBL for engineering students in their final year projects. This process involves individual’s (i.e. student and instructors) involvement in the evolution of teaching and learning process. It was shown that PBL would be effective if teaching and learning methods are meticulously set in terms of course preparation, scenario design, implementation, and assessment. Implementing of PBL in a course can result in higher levels of students’ and teachers’ satisfaction, and foster the teachers’ development of their teaching knowledge foundations to promote students’ knowledge, critical thinking, and interest. Based on this, MUSIC motivating components were used to characterise the effectiveness of PBL in active learning during a capstone project. These motivating opportunities are important because they can help instructors to plan and implement PBL instructions more effectively and improve student’s engagement. The findings in this article can help to improve students’ success beliefs by making course expectations clear, assess students at an appropriate level, and providing continuous feedback.

Finally, authors believe that a larger set of students from different engineering disciplines should be surveyed in future research in order to achieve more statistically significant evidences.

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