Interdisciplinary learning for final year engineering projects: case studies

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***Abstract**: Recent research has highlighted that today's engineering graduates need to have stronger interdisciplinary communication and teamwork skills as well as a broader perspective of the issues that concern their profession such as social, environmental and economic issues. We review a number of interdisciplinary project based case studies to determine what motivates students to learn and achieve and compare our experience with Problem Based Learning (PBL) and Project Based Learning (PjBL) frameworks. Our analysis uncovered factors other than those traditionally identified in PBL or PjBL that appear to play a significant role in learning achievement.*

Introduction

A review of the predominant issues of concern in engineering education by Mills and Treagust (2003-04) reports that today's engineering graduates need to have stronger communication and teamwork skills and a broader perspective of the issues that concern their profession, such as social, environmental and economic issues. Students are graduating with good knowledge of fundamental engineering science and computer literacy but they don't know how to apply that in practice. According to the US National Assessment of Educational Progress, while students are learning the basic information in core subject areas, they are not learning to apply their knowledge effectively in thinking and reasoning (e.g., Applebee, Langer, and Mullis, 1989). Another issue is isolationism. It has become common, especially in the Honours year that students work on a unique project on their own (commonly with the help of a supervisor). This approach can lead to isolation and less communications with peers. It has been shown that knowledge derived from isolated learning is more difficult to process and recall (e.g., Repko, 2007).

In a real work environment, projects are usually interdisciplinary, requiring knowledge, skills, expertise and an understanding of the overall process of development of a product. Mills and Treagust (2003-04) reviewed a number of major critical issues of the philosophy and delivery of engineering education and one recommendation was to employ interdisciplinary project based learning. They claim such environments promote interdisciplinary communication and knowledge development. Interdisciplinary learning provides a meaningful way in which the participants can use knowledge learned in one context as a knowledge-base in other contexts in and out of school (e.g., Collins, Brown, and Newman, 1989). It develops mutual understanding of and respect for contributions of other disciplines. It helps creating socialization and competencies for collaborative practice. Successful completion of projects in practice requires the integration of all areas of an engineer's undergraduate training (e.g., Merrill, 2002). The capability to transfer the acquired knowledge, skills, problem solving abilities and expertise from one domain to another is a very crucial attribute for persistent and true learning.

Problem Based Learning (PBL) and Project Based Learning (PjBL) are two student-centred learning pedagogies that are being increasingly applied to engineering education and address some of the issues above (Shi, 2010). They reflect a growing recognition of both the benefits of active learning and the importance of engineering students developing robust professional skills (e.g., Beddoes, Jesiek, and Borrego, 2010). In PBL the students learn about a subject in the context of complex, multifaceted, and realistic problems (e.g., Mills and Treagust, 2003-04). PjBL employs in-depth and rigorous classroom projects to facilitate learning and assess student competence. Students use technology and inquiry to respond to a complex issue, problem or challenge.

Four case studies of interdisciplinary projects were conducted at the University of Western Australia (UWA): 3D Cartoon Movie, the UWA Virtual Universe, Google Earth, and UWA Second Life projects. The first project was a standalone project while the latter three were in a sequence of projects but not designed along formal PBL or PjBL guidelines. We analyse the case studies to identify what excites and motivates students to achieve learning and project goals and relate our observations to PBL or PjBL approaches. In each project we have set a number of goals to achieve. We recorded the challenges and advantages of them.

STUDY 1: Making a 3D Cartoon Movie

The objective of this case study was threefold: to explore the challenges and benefits of interdisciplinary PBL framework within a project; to investigate what excites the students most and how they behave in an interdisciplinary environment; and to have a successful outcome - product. The project was divided into a range of sub-problems with components from various disciplines. For an enjoyable and successful cartoon movie the major requirements are: a charming story, model and characters design, model movements, sounds and music, special effects and video, and finally, integration. These aspects required skills from many different disciplines. The participating students directly learnt how to work and communicate in a cross-disciplinary environment and build networks amongst peers from different disciplines. They benefit from understanding the views and requirements from different perspectives. With the progress of the cartoon movie making, various interdisciplinary PBL challenges were encountered. Since UWA does not have formal interdisciplinary learning curricula, for this particular project we needed to call for volunteer participants from various schools through the school heads. At an initial stage it was anticipated that this project would be a fully voluntary project and no credit will be given towards academic grades. However, we did not have that many responses and later we decided to bring more incentives into it and made it a part of the project unit for Honours students. We then had a large number of interested students. Early dropout was another challenge. After expressing an initial interest, a student from one of the schools did not participate throughout. We also have had resistance from other participants for example, one of the Mechatronics students claimed he was there to learn mechanical engineering not computer software; or we are to learn IT (Information Technology) not motion control. A detailed problem based planning of the entire project with a set time frame was in place so it was possible check and balances the progress of the students. We succeeded in creating a good quality 3D animation video clip. The participating students have had the training on how to work in a multidisciplinary environment which resembles the real life work environment.

STUDY 2: The UWA Virtual Universe Project

This project's goal was to recreate parts of the university accessible to everyone, everywhere, in a 3D multiuser virtual environment (e. g, Arulpragasam, 2008). The team was formed from respondents to email invitations UWA wide and to select international lists. The team grew quickly to form a brilliant cross-disciplinary team including UWA staff, visiting students from Mexico and Brazil, alumni of UWA and interested parties from Finland, Thailand, Canada, New South Wales, Queensland and the United States (University News, 2007).

Although the team found the hard work, the teamwork dynamic was excellent because everyone was working on a vision all believed in Students learned to design 3D models for Web delivery, lay them out on a larger plan, make an interactive multiuser environment: developing both client and server. They also learned: teamwork with people from different schools and faculties, and a wider international community, to use their initiative to improve process and efficiency, time management, to build parts of a larger software/model that others required for their parts (i.e. they had to become aware of which of their tasks were on the critical path), participation in project coordination and operations, working under time pressure to meet hard deadlines, estimating, tracking.

One of the most important outcomes was in getting the team together, and in getting some publicity and visibility for the project among members of the University community. The project succeeded in demonstrating a limited multiuser virtual space featuring parts of the University, at SIGRAPH 2007 in San Diego, CA. People from different parts of the world were able to choose an avatar and meet within the virtual space. However, it lacked the functionality to really grow. An unanticipated outcome impacted the international community: the work lead directly to the realisation that the Web3D ISO standard lacked support for multiuser communication and strong networking. As a result, the Web3D Network Working Group (Web3D) was formed. The group developed a proposed enhancement to the X3D specification, the Network Sensor node (e.g., Thorne and Daly, 2007) which has since been implemented and referenced by a number of X3D technology developers and researchers (BS Collaborate, Octega Nodes).

STUDY 3: Google Earth project

This project formed from a team that entered a Google “Model your campus in 3D” competition for Australia and New Zealand (e.g., Malkovic, 2008). We decided to stay with the informal PjBL methodology used in the last project because of its success in building the communication and teamwork skills identified as a major concern by Mills and Treagust (2003-04). Team members had to take on different responsibilities: project management, modelling, image processing, photography, model library coordination, and submission management.

Students learned similar project skills to the Virtual Universe Project: project deadline, communication, collaboration, and deliverables. Fortunately, the main modelling tool, Google Sketchup, was the same so those who worked on the previous project did not have to learn as much. In addition, students had to solve a number of spatial and skill based problems while dealing. For example, they needed to find efficient and effective ways to convert differing 2D building plan representations into 3D with the stipulated tools. One student found through experimentation an optimal image compression value for jpegs that did not perceptibly reduce image quality. Another student created a wiki for coordination and recording knowledge and lessons. The wiki was a perfect adjunct to email and chat.

The project was successful beyond anything the team envisioned. Despite a lack of monetary incentive, a significant learning load, short time scale and task times being generally underestimated, the drive to achieve was strong and the results so “rewarding” that the team produced more high quality models than other teams. UWA were the winners of the competition out of the 33 registered teams. There was significant publicity both in local and national newspapers, leading to high level recognition and to successful bids for financing that came in from various parts of the University including the Vice-Chancellery as well as private organizations (Systemic Pty Ltd). The models are now on Google Earth 3D layer and used by the University staff for showcasing the University, for visualising buildings and development planning, and by the general public or prospective students who wish to see what the University looks like.

The fact there was no prize money did not appear to hinder progress. Hence, other factors drove achievement. The team was enthusiastic and hard-working. This, in itself, encouraged collaboration. As most of the team had worked together on the Virtual Universe Project there was already a cohesive core group. The team was also highly motivated to compete, achieve a high quality result and gain public q-dos, with the prize being a secondary motivation. All worked together on learning and teaching each other new skills. There were no drop-outs.

There was room for creativity. One student reported "the feeling that you're optimising your process as you go was a great motivator". The tasks were well defined. It was known ahead of time that it was achievable. Students reported they enjoyed the constructive work. One said the contrast to solving more academic problems was a "recreational break" from set coursework. Team members knew that the outcomes would be useful to others and this motivated some members to put in some extra hours in exchange for greater quality. They knew that the work would be easily accessible via the Internet, so there was a low-barrier way to showcase one's work.

STUDY 4: UWA Second Life Project

This project allowed for the full realization of one of the initial Virtual Universe Project goals: recreating UWA, including the architecture, flora and fauna as well as allowing international interaction and collaborations within the engaging virtual UWA presence. The previous wiki, chat and email were used for core team member communication.

Students learned similar skills to the other projects: deadlines, communication, collaboration, and deliverables. Although students also designed 3D models and deployed them in a wider virtual space new 3D design and modelling skills and tools were required because Second Life modelling requirements and tools are very different from most other virtual environment products. This made estimation and meeting deadlines as difficult as in the Virtual Universe project. In this project there an even bigger sense of being part of a wider national and international community because a greater number of national and international participants joined in and one could interact with them directly through avatars in virtual spaces.

There was strong team working relationship and enthusiasm but this time payments could be made for significant portions of work due to the funding that the project had attracted. Relationships and levels of involvement changed dramatically however once the virtual University was built. The focus shifted to the running of teaching activities, the demonstration of the viability of the medium for research into 3D Visualisation, the use of the medium to develop architectural plans and the running of an international 3D Art challenge as well as an international video animation challenge, with new expertise being drawn on with all these different components.

Challenges included insufficient funds - to recreate the full campus and all the desired activities, with a lot of pro-bono work being done. The goals have always been shifting however as many of the most successful parts of the project (i.e. the Teaching & Art & Video Animation) all came about through chance and serendipity. The organic nature of the project and the flexibility of the leaders to allow for this have been vital in its success. The project generated enthusiasm from around the world as to UWA active presence and has attracted an incredible amount of publicity for the activities carried out by UWA. The project was recognised as one of the 100 Treasures from UWA, and also nominated into the top 10 from 130 projects world-wide for the 2010 Linden Prize (Dobie, 2010).

Discussions

The cartoon project was designed within a PBL framework. The other three case studies were essentially project based but shared two things in common with PBL: the student centred aspect and students active interest in activities. In contrast, lecture based activities have revealed "passive" interest or even disinterest, as attested by Ward and Williams: "As a consequence of such traditional [lecture based] teaching practices, students are at best passively involved in the learning process (Scott, 1997)" (e.g., Ward and Williams, 2001). The active interest may be due to common elements found in both PBL and these projects, such as the following identified by Ward and Williams: Critical thinking; Problem evaluation; Oral and written skills associated with the communication of problem analysis; The ability to work as a member of a team.

Factors we attribute as leading to success in learning and achieving goals, particularly in the three UWA virtual reality projects made up of multidisciplinary teams were:

- Project concepts that engage participants' imagination.
- Strong motivation of individuals to work together.
- A competitive element to achieve goals.
- Knowledge that the work would have longer term value to the University and other people.
- Being part of a growing wider community.
- The work was considered "recreational" relief compared to traditional engineering learning experience.
- The opportunity to be creative also excites the learners.
- A cohesive core team that persisted across projects.

An effect that may have been the greatest contributor to success is working of providence "described by Goethe: . . . the moment one definitely commits oneself, then providence moves too. All sorts of things occur to help one. ... A whole stream of events issues from the decision, raising in one's favour all manner of unforeseen incidents and material assistance... . Whatever you can do or dream you can do, begin it. Boldness has genius, power and magic in it, begin it now" (e.g., Goethe, 1832). On these projects, people from other parts of UWA and the world joined in and contributed - often for free. These contributions were often significant help in achieving successful outcomes and generated new ideas and activities.

Cheaney and Ingebritsen say in any learning situation, student attitudes greatly influence the degree to which learning can occur (e.g., Henderleiter and Pringle, 1999) and many students report motivation as a prime difficulty in their evaluations at the end of the semester. In our observation, students showed strong motivation which we attribute to competitive spirit, knowledge of longer term value, engaging or exciting project concepts, and possibly the sense of being part of a wider external community (for the Virtual Universe and Second Life projects). The local team also enjoyed networking with the wider global community and this contributed greatly to individual learning.

The 3D cartoon and Google Earth projects were the most detailed and constrained in scope. The cartoon project was also the most realistic in terms of expected achievements but there was less self investment by students in the project. However these factors seem to be less important because the poorer scoping of the other two did not prevent successful outcomes. The cartoon project started in a way common with the other projects; however, in this case there was not a strong initial uptake until it was made part of a formal honours course.

Conclusions

It is notable that the 3D cartoon project attracted more interest when made into a formal project and the reasons behind this should be investigated further. However, the project did not gather the same kind of force multiplier momentum from within the University and externally that the other projects demonstrated. There were multiple clearly identifiable positive outcomes from the projects that were more inclusive of a wider, open community, despite their somewhat lofty goals. The most notable being the development and implementation of the Network Sensor in the X3D ISO standard and for the UWA Second Life project, its inclusion in the 100 treasures of UWA and the multiple outstanding online awards and events attributed to the project.

These studies suggest there are factors affecting learning achievement in addition to or even transcending those parameters so far used to evaluate PBL and PjBL. Individual teachers, and more crucially educational institutions in a broad sense, may therefore benefit from further investigation into the social and psychological mechanisms at work in learning that go beyond current PBL and PjBL pedagogies. Factors future research could focus on are:

- Is the working of providence as described by Goethe something that should be deliberately promoted by the education program? The general open inclusive approach of three of the projects attracted a serendipitous providence that appeared instrumental to their success.
- Should units incorporate recreational \relief" elements? Some of the project work, although challenging in time and effort, was considered a \relief" from engineering problem focused learning activities.
- What were the reasons that lead to an increased interest in the cartoon project when it was made into a formal course?
- Should some element of competition be incorporated in to courses?
- Does involving a wider, even international community improve motivation?
- Should project outcomes have clearly identifiable longer term application by a known group or customer? The promise that the results would have ongoing benefits and use seemed to be a major motivating factor.

Such a study could measure the contribution of these factors to learning success in comparison to PBL or PjBL approaches. We feel it would an honours level course would be well suited to formally evaluate the above factors because it allows for extended projects with wider scope compared to the much shorter and constrained projects of undergraduate courses.

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