Project-Based Learning: A Search and Rescue UAV – Perceptions of an Undergraduate Engineering Design Team: A Preliminary Study

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Abstract: *The aim of this paper is to provide a voice for students about project-based learning in an undergraduate education setting. During their final year of a four year undergraduate engineering degree a group of 8 students successfully designed, developed and manufactured an autonomous search and rescue Unmanned Aerial Vehicle (UAV), as an integrated project-based learning part of the curriculum. The use of project-based education in undergraduate engineering courses has been discussed in the literature on pedagogy in higher education. However, little has been discussed about the students' own perceptions of the use of project-based learning and teaching. In this paper students undertaking a final year Design Project course reflect on both the learning process and the outcomes of the year long search and rescue UAV project. This discussion represents a preliminary overview of the students' findings and provides a basis from which to conduct further, more detailed, investigations at a later stage.*

Introduction

Project-based learning is an educational process through which knowledge, principles and practices can be developed. Project-based learning is particularly pertinent in engineering education as the majority of professional engineering work is conducted through projects. Therefore, it is logical to integrate project-based learning into undergraduate engineering education, alongside traditional, classroom-style coursework.

Project-based learning offers an engaging means of education for students in engineering related coursework. Traditional coursework consists of extensive presentation of engineering science theory followed by a series of assignments, papers or examinations in order to assess the students understanding of the theoretical material. Project-based learning offers a medium through which students can apply this engineering knowledge in a real world project, in order to meet a real and practical project objective. Through this means the students are able to directly create the link between the theoretical knowledge and the practical problem. The desired outcome of the level four (final year) projects, from the University's perspective, is to produce engineering graduates with the following attributes articulated by Engineers Australia:

- ability to apply knowledge of basic science and engineering fundamentals;
- ability to communicate, not only with engineers but the community at large;
- in-depth technical competence in at least one engineering discipline;
- ability to undertake problem identification, formulation and solution;
- ability to utilise a systems approach to design and operational performance;
- ability to function effectively as an individual and in multi-disciplinary and multi-cultural teams, with the capacity to be a leader or manager as well as an effective team member;
- understanding of the social, cultural, global and environmental responsibilities of the professional engineer, and the need for sustainable development;

- understanding of the principles of sustainable design and development;
- understanding of the professional and ethical responsibilities and commitment to them; and
- expectation of the need to undertake life long learning, and the capacity to do so.

Project-based methodology encourages students to critically analyse issues and to solve 'real-world' tasks in an educational setting, which establishes strong engineering judgement and decision making thought processes that otherwise takes significant practical engineering experience to develop. Through this process the students are able to more easily bridge the gap between university and industry, equipping graduates, as mentioned by Wang et al, (2005), with attributes such as teamwork and solution synthesis skills required for industry.

Current literature on project-based learning predominantly focuses on the opinions of academics on this form of education (eg., Garrison, 1999, Doppelt, 2005, Wang et al 2005). This paper discusses the outcomes of graduating engineering students involved in a project-based learning case study, and focuses on the personal perspectives of the participants. The significance of this paper is that it is based on a student initiated research of project-based learning in engineering education. The information analysed is intended to present initial findings of one particular group of students from the student's own perspective.

There is an overwhelming theme in the literature, as discussed by de Graaff and Ravesteijn (2001), that the role and skills of the professional engineer need to change to match the evolution of modern engineering methods. As stated by Missingham (2006), the need for engineering students to acquire professional skills and non-technical skills has been increasingly stressed by educators and industry representatives alike. Project-based learning also gives students exposure to education in a manner, which is both fun and motivating, whilst enforcing the knowledge gained in a variety of coursework through connection to a real world application (Malmqvist, et al., 2004). In addition, skills such as cooperation and teamwork can be developed through project-based learning; these skills are not always developed by students in a traditional classroom environment. Thus, project-based learning offers an effective means of developing the required skill set, complementary to the traditional coursework-style of learning.

An example of project-based engineering education is the project undertaken by four aerospace engineering students and four mechatronic engineering students at The University of Adelaide. The group of eight consisted of a diverse range of individuals, including one female member, one international student and one mature aged student; they were set the task of the design, development and manufacture of an Unmanned Aerial Vehicle (UAV) for civil surveillance applications. The students were responsible for all facets of the project, many of which were either not taught or overlooked in lieu of deeper theoretical understanding in their classroom-based courses. In particular, the undertaking of the project required non-technical, 'soft' skills, such as human resource and financial management, which are more difficult to develop in a classroom setting, but which contribute significantly to the positive and professional development of an engineer, as mentioned by Selinger (2004) and Dym et al. (2005). The effect on learning of both technical and soft skills by undergraduate engineers through project-based learning are discussed in this paper, through the reflections of students involved with the development of this UAV.

The technical learning associated with the project contributed to the successful delivery of an autonomous UAV. This included the design, development and manufacture of the airframe from conception, as well as the development and integration of all systems required for autonomous flight and real-time surveillance. Design requirements were developed for meeting the entry requirements to the Australian Research Centre for Aerospace Automation (ARCAA) UAV Outback Challenge, which was held in Kingaroy, Queensland in late September 2007. The result was a UAV platform with the following attributes and performance capabilities:

- 10 *kg* maximum take off weight
- 2 *kg* maximum payload
- 2 *m* wing span & 1.6 *m* in length
- 1 *hour* flight endurance
- 1 *hp* brushless electric motor

- 90 *km/h* cruise speed
- 10 *km* operational range
- Autonomous flight capabilities
- Real-time video feedback, with 450 *TV-lines* of resolution
- Parachute system for emergency and vertical vehicle recovery

In addition to the technical learning, the project resulted in the successful development and education of the students in non-technical, 'soft' skills, which, as previously mentioned, are not traditionally taught, or otherwise ineffectively taught within a classroom setting. Examples of the soft skills the group members were exposed to include systems engineering, project management, procurement of funding, financial management, risk assessment, logistics, interpersonal communication and team work.

The paper presents preliminary findings of research into project-based learning, and discusses the effect of project-based learning on the education of one group of undergraduate engineers, as perceived by the students themselves. These findings will serve to inform a more detailed study into project-based learning, investigating learning outcomes from graduate student perspectives, taking into account a larger demographic, focussing on individual factors to the students, such as available resources, pre-existing skill sets, motivation, and engagement in the process.

Student perceptions of learning processes

Methodology

Much of the current literature on project-based learning has been presented from the perspective of academics (e.g. Garrison, 1999, Doppelt, 2005, Wang et al 2005). This section presents the results of a student survey that has been devised and implemented by the students themselves in order to examine student perspectives of learning in an engineering student project.

Student members of the Unmanned Arial Vehicle Project group have designed and implemented a research approach and analysed information resulting from a survey circulated amongst the group members. In order to accurately assess the students' learning a combination of quantitative and qualitative measures has been utilised. The student survey was developed in two parts, the first being a Likert scale survey, a proven research procedure that has been extensively validated in surveying of feelings, attitudes and perceptions, and the second part consisting of three open-ended questions. The Likert survey was designed, as a five-point scale, to examine the perceptions of the students regarding the final year project, its contribution to student learning, the development of interpersonal and communication skills and the education in a holistic engineering project. This section comprised 14 questions in total and students were required to record a score between 1 to 5 for a given statement; with a score of 1 representing 'strongly disagree', 5 representing 'strongly agree' and 3 representing 'neutral' response towards the statement. The three open ended questions investigated the student's perceptions of the importance of the project in terms of their own education, the development of engineering knowledge and understanding of an engineering project and the thoughts on team and group working.

Results and Discussion

The Likert Survey was distributed to the eight members of the project group and analysed to give results relating to the students' perspective of project-based learning. The results provided an insight into the relevance and educational merit of project-based learning. As the results suggest, project-based learning provides a unique practical experience that was received well by the students. The involvement in a project with real objectives has an effect on the learning of technical and professional skills and, as highlighted by various authors, (eg, Missingham, 2006, de Graaff and Ravesteijn, 2001, Selinger, 2004) these are skill sets desirable for engineering employers. These effects are highlighted by the results of the survey, and discussed with reference to the comments of the participants of the survey.

Students supported the integration of the project with their educational experience. All students agreed, with 62.5% strongly agreeing, that the project is a necessary component of a Bachelor of Engineering. This was further supported by comments from the open ended questions that stated that the project "*provided practical experience*" and "*good experience to have going into the industry*".

Furthermore, 87.5% of the group either agreed or strongly agreed that the project was a rewarding experience, with one member having neutral feelings towards this statement.

Having had prior undergraduate coursework and lectures relating to engineering projects 50% of students strongly agree and 50% of students agree that the undergraduate project has developed their understanding of the scope of a holistic engineering project. Thus the experience has developed the students' understanding of an engineering project through the practical exposure of an undergraduate engineering project that has helped prepared them for their future careers.

The effect of project-based learning on the development and learning of engineering theory in a practical environment was investigated through the survey. One student commented that, "*the change from heavily constructed assignments, which focus on one particular technical aspect to a holistic engineering project in which all developmental steps needed to be considered provided for much learning*". This comment reflects the fact that 62.5% of students agreed or strongly agreed that the practical aspects of the project enhanced his or her understanding of theoretical concepts taught in the classroom, with the others having a neutral response to this statement. One student also commented that the project, *"(reinforced) old skills taught in previous years which may otherwise deteriorate or be forgotten*" highlighting one mechanism through which this enhanced conceptual understanding occurs.

62.5% of participants also agreed that the project extended his or her technical capabilities. It was mentioned by one student that problems were overcome through reading of literature and personal research. This suggests that knowledge not taught in the classroom was required to complete the project; thus the student obtained additional technical expertise, unable to be taught within the constraints of a classroom based curriculum.

Contrary to these positive results, 25% of participants disagreed that the project enhanced his or her technical understanding, and 12.5% disagreed that his or her technical capabilities were extended. Relating to these results, one student mentioned that the technical skills learnt were irrelevant to an engineering field. Reflection of these results and comments indicates that project-based learning may not guarantee the development of technical expertise and that ultimate outcomes with regards to technical expertise may depend on other factors, such as project task allocation: investigations beyond the scope of this initial research study. The results do, however, demonstrate that some participants consider that they have received positive development of technical skill sets.

The project has provided students with the opportunity to develop non-technical engineering skills that would not normally be developed in an engineering education setting. In response to the statement 'The project has provided knowledge in areas unable to be effectively taught in a classroom, eg managing teams, time frames and finances' all students agreed with half strongly agreeing. This strong positive response was further reinforced by responses to the open ended questions which included "*…developing many generic skills that could be applied to a range of projects, relating to areas such as project management, the importance of time-lining, working in a large group etc. These are areas that are often talked about but never really developed elsewhere in the engineering degree on this scale*". The consistent student agreement for the group surveyed demonstrates that the practical application of these non-technical skills is a more effective way of developing such a non-technical skill set, vital for engineers as highlighted by Selinger (2004).

The structure and requirements of the project necessitated the use of the interpersonal skills of the group members amongst themselves, as well as between other personnel key to the success of the project. This scenario provided an avenue through which the effect of project-based learning on the development of interpersonal skills, and the ability of group members to work with a diverse range of people, could be investigated. Only 62.5% agreed that the project directly developed interpersonal skills through interaction with other personnel key to the project. Furthermore, even with the diverse demographic characteristics of the group itself, and the number of external personnel involved with

the project, only 50% of the members felt that the task benefited his or her abilities to work with a diverse range of people. While these combined statistics appear to indicate an inconclusive result, no one disagreed with these two points. Therefore it is suggested that project-based learning provides a complementary mechanism for the development of interpersonal skills, with applicability based on the personal experiences of individuals. This supposition will be investigated in a later study of a larger cohort of the same graduating class.

Many students commented on the ability of the project to develop skills with regards to conflict management and human resource allocation. 87.5% of students in the UAV project acknowledged that the project taught them the importance of group work, one student, commenting that conflict *"…can prevent the group from acting as a team and inhibit the progress of the project*". Other comments made by students mentioned mechanisms developed throughout the project and used by the group to resolve conflict and maintain the focus of the project. The other 12.5% were neutral; again, it is suggested that this response was due to the extensive prior professional experience of the respondent. Honest, open forum discussions regarding conflict and the allocation of human resources to tasks with consideration to personality traits were said to be two ways used by the group to deal with and resolve conflict. Consequently, project-based education was shown to support the learning of management practices and the benefits of effective team work through practical exposure.

The project has developed a degree of vocational awareness among the students. 62.5% of students either agreed or strongly agreed that the project was a true representation of a real engineering project, with the other members having neutral feelings towards this statement. This result is supported by other student views presented by Wang et al. (2005) who also found that students are exposed to realistic engineering work through project based learning. These findings indicate that the majority of the students believe that such a project has given them exposure to an engineering work style without leaving the undergraduate education setting. Interactions with suppliers, technicians and other personnel have increased the awareness of five of the participants to the other personnel key to the success of an engineering project.

This is further supported by the comment that the project led to *"…the development of skill to converse information, ideas, requirements, etc. (to non-engineers) in a way which ensures tasks are completed on time and satisfactorily*". The remaining students recorded a neutral response. Consequently, the majority of results support the notion that project-based learning provided participants with positive insights into the professional engineering environment, providing graduates with a greater vocational awareness at the outset of their careers.

Project-based learning offers a medium to develop professional conduct and pride in the material students produce. 75% of students agreed that project-based learning taught them how to effectively fulfil a position in an engineering team. Strong support for this was evidenced in the time committed to the project by many members. Over a 30 week period, all students committed between 500 and 1000 hours, in comparison to the recommended 400 hours suggested by course coordinators. This commitment demonstrates the developed dedication of all members to ensuring that the project was a success, and that he or she contributed to the best of his or her capability; this further relates to the development of professionalism as discussed by Wang et al. (2005). 25% of participants did, however express neutral feelings towards learning how to effectively fulfil an engineering role. While it is suggested that this neutrality may be attributed to the prior experience of the respondents in a variety of professional engineering roles, this is an area which will be further investigated in the proposed detailed study.

Concluding remarks

The evidence presented supports the authors' own experiences that project-based learning is an effective form of engineering education, which complements the traditional classroom style education method to better achieve graduate attributes. The synergy between project-based learning and more traditional course work has been highlighted throughout this case study. Despite this synergy it should be noted however, that the benefits associated with project-based learning vary between individuals. It is suggested that this may be due to the involvement of students with various levels of professional experience, as well as the allocation of project tasks, which may or may not develop the skills of the

student, again depending on his or her own pre-existing experiences and skill set. However, the results of this preliminary study do highlight the importance and development of non-technical skills among the student cohort of this study, demonstrating the effectiveness of project-based learning to address some of the expectations and graduate attributes of students. The results of this study also reinforce the need for a more detailed examination of student perceptions of their own learning, through a project-based based approach, as well as in relation to achieving the learning objectives of the course. Initial indications revealed here will therefore provide the basis for extending this study to larger cohorts of graduating students in Mechanical Engineering at The University of Adelaide.

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