Australasian Association for Engineering Education Conference
AAEE2015
GEELONG 7th-9th December

A Multi-Disciplinary Project to Enhance Workplace Readiness

Introduction

Engineering graduates are expected to develop a breadth of competencies to prepare for the workplace, encompassing technical knowledge, problem solving and interpersonal skills (IPENZ, 2009). Engineering education often focusses most on the development of students' technical and problem-solving skills and less on the interpersonal skills (Bodmer, Leu, Mira, & Rutter, 2002). This weakness in graduates' communication skills has been identified by organisations such as UNESCO. "There is ample evidence that graduate engineers lack the required standard of **communication skills**, particularly when compared to the needs of industry internationally" (UNESCO International Centre for Engineering Education, 2002)

Some engineering programmes attempt to develop students' complementary 'soft skills' by including compulsory modules such as Communication skills. At Wintec, these modules are taught by communication specialists, who are non-engineers. However, there is a genuine effort to use engineering contexts for the learning tasks and assessments in these modules, this is sometimes contrived rather than directly applicable to the students' learning in their specialisations. Recently, the authors' Wintec colleagues have incorporated the NZDE communication assessments and incorporated them into an intensive *Disaster week* (Bigham & Harris, 2014) project to achieve an engineering problem-focus in the writing and presentations for students. This approach has been adopted to align with the work of Martin, Maytham, Case & Fraser (2005) who explain that "non-technical skills cannot be taught in isolation from the technical context in which they will be used" and further suggest that "integrated projects are a crucial tool" to achieve this.

This paper focuses on a continuation of this theme, but this time looking at project based learning extended to include multiple disciplines with more challenging technical content.

Background

In 1998 (Peschges & Reindel, 1998) identified desirable attributes and skills for engineering students "Students, who are tomorrow's employees, also need: the ability to work in **teams**, **communication** and **creative** abilities, the ability to recognise and understand **problems** from different viewpoints". Work by (Bodmer Leu, Mira, & Rutter, 2002) has also concluded that "communication skills, English language skills and teamwork abilities are regarded as the most important general professional competences for engineering graduates". The recent

IPENZ, 2009 graduate competencies also align with this work, with Teamwork and Communication being Personal Qualities that figure highly in the graduate profile (IPENZ, 2009).

To build these competencies in engineering students Martin et al (2005), recommended that "non-technical skills cannot be taught in isolation from the technical context in which they will be used" This implies that such soft skills should be embedded in the teaching and learning of technical content. One of the recognised tools for achieving this is Project Based Learning (PBL). Projects generally are within their particular engineering discipline, however as Martin et al (2005) points out "engineers never work alone in industry", and so a multidisciplinary approach is also required to prepare students for the modern workplace.

The concept has recently been applied at Waikato Institute of Technology (Wintec), to enable students in the Bachelor of Engineering Technology (BEngTech) to experience the type of challenges they will be exposed to in the modern workplace. The students were tasked with designing and constructing an autonomous manufacturing system, as part of their 'Manufacturing Process and Production' and 'Programmable Logic Controllers (PLC)' modules, in the Mechanical and Electrical streams of the BEngTech. Each team consisted of two mechanical and four electrical engineering students, working at level six and level five respectively. Students worked outside of their normal class times for 8 weeks to complete the project, which required the students not only to demonstrate their completed manufacturing system, but also collaborate to produce a professional Systems Operation Manual. Within the project there were common and discipline specific responsibilities and mark allocation was split accordingly. The contribution of the overall project mark towards a student's final grade was different for each module as required by programme requirements.

The level of detail provided in the project brief for the students was balanced between being broad enough for students to apply their creative problem-solving skills, but prescribed enough to ensure that the task fitted the assessment requirements of the two programmes and was achievable in the time allocated. The project required the students to develop their team work and communication skills to design, produce and demonstrate a working prototype.

To evaluate the success of this tool in the student's learning the author's conducted a research project in parallel with the project. The research analysed the development of the students' non-technical skills and their ability to work within a multi-disciplinary team to achieve their goal. The following sections will detail the methodology used for data collection, the findings and the discussion and implications for the next iteration of the project.

Methodology

The authors used an action research based methodology to conduct this research project. Ethics approval was granted and student consent was obtained. Data was collected from the participants in this study primarily through questionnaires, first at the outset of the project and then midway through. The questionnaires comprised qualitative and quantitative questions which were included to provide a range of data for analysis. The questionnaires were used to assess students' perceptions of their involvement in this project and the performance of their team against the project requirements. Data was recorded and anonymised by an administration support staff member, in order to protect the privacy of students through the comments that they submitted in surveys. Each student was allocated a number to allow comparisons of data through the stages of the project.

Students also submitted a final reflective essay which provided insights into their feelings about their own performance and the team dynamics. Having these reflections in the students' own words gave an honest view into their learning and personal development from this challenge.

The authors' observations of teams' performance were also noted. When students approached the authors for assistance in their respective areas of expertise, these interactions provided opportunities to evaluate performance of the group against the project brief and against the desired 'soft-skill' development goals. This informal feedback was helpful in understanding the dynamics of the teams and constraints that students faced in developing a working prototype.

The quantitative results from the two surveys were used to determine a mean score for each rating-type question. Responses to qualitative questions from the survey were used to support the quantitative findings. The qualitative data from reflective essay were coded according to the themes which emerged. These findings were then cross-referenced against the academic staff members' observations of team dynamics and performance. The findings from the data collection are outlined below.

Findings

This section will look at the findings from our data collection tools, the surveys and reflective essays:

Survey data:

Survey data was collected at the beginning and mid-point of the project. 38% of the students responded to the initial survey, and a similar response rate was also measured for the mid-point survey. The questions asked in the surveys were to probe the student's expectation of their teams and their personal ability to complete the project allocated. The findings are outlined below:

Team capability and organisation

The data from both the initial and mid-point surveys showed that the students were confident in their team's ability to succeed with the project, with ratings of 77% and 83% respectively. What is interesting to note is that at the time of the mid-point survey the students rated their team's level of organisation needed to complete the project at 75%.

Self confidence

Initially the students were generally very self - confident in their ability to meet the project requirements (87%), however as the project progressed the level of self-confidence decreased to 71% at the time of the mid-point survey.

Cross-discipline benefits and challenges

The qualitative results from both surveys focussed on the students perceptions of being part of a cross-discipline project. From the initial survey one student identified a benefit of the project as a "feeling of working out in the industry, face to face with your co-workers (classmate) and bosses (teachers)", while another mentioned that the project allowed them to “experience possible real world situations”. A number of students mentioned the benefits of increased awareness of working with other engineering disciplines “understanding between two fields of engineering”.

The initial survey results also raised a number of challenges perceived by the students, namely communication between students around discipline-specific technical language “Mechanical students have their methods of communication and technical language which electrical students might not understand”. Another student commented that one of the main challenges was that they were “not understanding the ideas and concepts because you do not have any background knowledge from the other class”.

The comments from the later survey showed that some of the biggest benefits so far was the development of “new ideas through collaboration”, “Being able to see both sides of a project progress” and be “able to learn something new from other engineering disciplines”. The biggest challenges the students commented on were around student commitment and availability around the project.

Reflective Essays:

The qualitative questions from the six reflective essays were analysed and a number of themes identified. Overall the themes were generally positive, and tended to focus around Communication (33%), Leadership & team work (33%), Planning (27%) and Self-awareness (7%). The main comments are listed in Table 1 below:

Table 1: Positive Themes from the qualitative data taken from the reflective essay

Theme	Proportion	Comments
Communication	33%	Importance of cooperation, Patience and listening Understanding and communicating with team members Solution focussed in the way that they worked.
Leadership & Team work	33%	Motivation Gaining experience in a lead role in a team, teaching and coaching of others Cooperation across different groups of students.
Planning	27%	Use of Gantt charts Completing allocated tasks Good reporting structure
Self-awareness	7%	“There is much more that I’d like to learn and it’s better to have someone as a guide”
	100%	

The negative aspects reported by the students focussed in three particular themes, namely Lack of planning (25%), Logistics (33%) and Leadership & Teamwork (42%). The comments are outlined in Table 2 below:

Table 2: Negative Themes from the qualitative data taken from the reflective essay

Theme	Proportion	Comments
Leadership & Teamwork	42%	People not showing up Uneven workload No team dynamics Communication difficult Poor motivation
Logistics	33%	Not enough time for the project Limited resources Access to the facilities Lead times for ordering parts
Lack of planning	25%	Not using the Gantt chart Wasting time – lost first 3 to 4 weeks No time for testing before final demonstration
	100%	

Discussion

At the outset both teams of students were confident in the abilities of their teams and themselves. As they progressed, working on the challenges of the project they gained a more realistic understanding of the benefits, challenges and difficulties associated with working in multi-disciplinary teams. This likely contributed to the lower confidence rating given by the students in the mid-point survey. This finding is interesting in terms of the expectation on graduate engineers to work within their capabilities, but also to be able to identify where they can develop their skill sets through continual professional development activities.

It became clear as the project progressed that the team with the best leadership structure and teamwork philosophy achieved the greatest results. There was a clearly defined management structure with reporting lines to the project manager, with specific roles delegated to the students with the required skill set. One such position was the head of the electrical team, who reflected that it was a “good experience as I’ve had very little experience in lead role, but after a few days the role came naturally”. He noted his awareness of his delegated responsibility and reporting duty to the head project manager for his team.

One of the project leaders reflected that they could have delegated more responsibility to other team members and that this would’ve both lightened their workload and developed useful technical skills in other team members. “At times I did feel as though having taken on these responsibilities may have been too much for me. This may have been reflected in some of the standard of our work.”

A few students did not commit themselves to the project work as fully as others. This resulted in some frustration for those in their team who were dedicated to the required tasks. Some students appeared to have motivation more closely driven by the marks allocated, rather than the challenge of the project itself. One student noted that “team members complain more about the structure of the project and the marking, rather than to think positive and give their best to contribute to this project”.

Many students' reflection identified the relationship between good planning practices and the ultimate success of their team's work. All teams prepared a project Gantt chart early in the process, but this was not always closely followed or regularly updated. One student project leader noted that "we didn't really follow the Gantt chart as planned" and "we even ran out of time for some sections". Another team acknowledged their slow start to working on the tasks "leaving things to the last minute" which created significant pressure in the latter stages of the project. They were subsequently unable to demonstrate a fully operational system.

Both teams' performance suffered somewhat due to having limited time invested in the testing and debugging phase. Under this pressure the differences in team dynamics became more evident and showed the commitment that some students were willing to make to achieve a positive outcome for their team.

Cooperation between group members across discipline boundaries was evident as a crucial element for success; a student from the group with a healthier dynamic said "the level of interaction required between the design aspects and the programming aspects of this project was incredible and it was great that the whole group was able to show their individual talents and produce a working manufacturing system". Another student from this group noted "every member of the group was patient and understanding of each other. There was constant communication for meeting times, during meetings and project plans". "All of us were constantly talking with each other to plan this project and ensure when the day of the demonstration comes that it would work. Whether that being in face-face meetings or Facebook. I also believe this to be because of the numerous discussions which helped to strengthen the relationship within the group and have a good understanding of each other, not only as students, but as people."

Through working as a multi-disciplinary team in this project, students have developed a strong awareness of the importance of good leadership and teamwork. They have experienced first-hand the relationship between teamwork dynamics and the results achieved. This experience and awareness prepares them well for their future in the engineering industry.

Conclusion

This work has shown that communication and teamwork between multi-disciplinary groups within a project is paramount to the success of the project. The evidence has shown that groups with well-defined management processes are better equipped to deal with difficulties that arise during the course of the project. For those groups where communication and team work are not so effective there is a tendency for projects to flounder and the likelihood of a negative project outcome is increased.

Through the use of the reflective essay the students have shown that they are aware of their broader professional development, with their discussion of leadership roles, reporting structures and communication using a number of different media. This self-awareness is important for work-ready graduates where employers and professional bodies require these life-long learning capabilities.

The Graduate profile developed by IPENZ (2009) lists the importance of personal development of Graduates very highly. While students might have technical knowledge, the ability to put this to use in a realistic engineering environment will only work with good communication and teamwork but also leadership and motivational skills. This multi-disciplinary approach to project based learning exemplifies how technical knowledge and 'soft skills' complement each other and why there is such a focus on the 'soft skills' as part of graduate profiles,

References

Bigham, A., & Harris, T. (2014). Disaster Week: A case study immersing first year engineering students in a disaster context to measure communication skills. *AAEE Proceedings*.

Bodmer, C., Leu, A., Mira, L., & Rutter, H. (2002). *Successful Practices in international Engineering Education.* Zurich. Retrieved August 2015, from http://www.ingch.ch/pdfs/spinereport.pdf

FutureinTech. (2015, July). *E-News for Industry*. Retrieved from Future In Tech: http://industry.futureintech.org.nz/enews/Industry/story.cfm?ID=65

IPENZ. (2009, November). *Graduate Competency Profiles.* Retrieved from http://www.ipenz.org.nz/ipenz/forms/pdfs/Graduate_Competency_Profiles.pdf

Male, S. A. (n.d.). Generic Engineering Competencies: A Review and Modelling Approach. *Education Research and Perspectives, 37*(1), 25-51.

Martin, R., Maytham, B., Case, J., & Fraser, D. (2005). Engineering graduates' perceptions of how well they were prepared for work in industry. *European Journal of Engineering Education, 30*(2), 167-180.

Peschges, K.-J., & Reindel, E. (1998). Project-Oriented Engineering Education to Improve Key Compentencies. *Global J. of Engng. Educ., 2*(2), 181-186.

Terrón-López, M. J., García-García, M. J., Velasco-Quintana, P. J., Gaya-López, M. C., & Escribano-Otero, J. J. (2015). Design and Implementation of a Comprehensive Educational Model: Project Based Engineering School (PBES). *International Journal of ERngineering Pedagogy, 5*(3), 53-60.

UNESCO International Centre for Engineering Education. (2002). English and Communication Skills for the Global. *Global J. of Engng. Educ., 6*(1), 91-100.