Full Paper

Introduction

The past decade has witnessed rapid changes in Engineering Education. These include advances in technologies, increasing industry demands, challenging professional accreditation requirements, declining availability of funding, and notably the global decline of student enrolments in engineering. In addition, there is a great number of Non-English Speaking Background (NESB) and low Socioeconomic Status (SES) students attending engineering courses at Victoria University (VU). Often entering students lack the prerequisites they require to succeed and thrive in engineering courses at tertiary level. Encouraging student learning and engagement and the development of graduate capabilities have become challenges of particular concern for VU, given its diverse and largely non- traditional student cohort. The university has struggled to improve retention rates and to produce engineers capable of meeting industry demands. The adoption of the Problem Based Learning (PBL) teaching and learning paradigm to engineering courses at VU commenced in 2006 is part of a strategy by the University to address these problems (Thorn et al. 2007).

PBL is an instructional, learner centred approach that empowers learners to conduct research, integrate theory and practice and apply knowledge and skills to develop a viable solution to a defined problem (J.R Savery, 2006). PBL requires substantial effort and commitment from lecturers to ensure that students develop the requisite communication and professional skills, as well as technical competencies. Consistent effort is required to bring students up to the highest standards and provide them with the personal and professional skills necessary to become lifelong learners and engineers equipped for complex and ever- changing professional demands.

Chief Scientist Professor Ian Chubb released the position paper (2013): "Science, Technology, Engineering and Mathematics (STEM) in the National Interest: A Strategic Approach". In the section titled "AUSTRALIA: 2025" of the paper, it stated that:

"By 2025 we should have reached a point where Australians will understand and value the science they use in everyday life, and where the STEM enterprise will be widely accepted as a central and visible source of solutions to societal challenges. The education system will provide all Australians with the capacity and confidence to make informed choices on complex matters where STEM offers options that have ethical, economic or environmental dimensions."

It also stated in the paper that "To recognise and take full advantage of the opportunities which STEM provides, Australia will benefit most if there is widespread and general STEM literacy throughout the community, complementing the deep expertise of STEM practitioners". "There is currently a general view that the level of scientific literacy and numeracy in the community is low. An understanding of science and how it works is essential for the community to make informed choices on issues that have a scientific basis. Education in STEM is the key to broadening and deepening the community's grasp of what STEM is saying and doing about the complex challenges facing society."

The levels of STEM literacy in the community can be improved through an increased engagement of the community with STEM.

The above significant issues have prompted the second year PBL staff team to develop creative and innovative PBL projects to not only improve students' problem solving skills and independence in learning but also promote STEM literacy throughout the community by drawing upon educational theories, particularly PBL principles, that emphasise motivated learning (Barrows, 1986) and personal skills and abilities development (Moesby, 2005), experiential learning (Kolb, 1984), active learning (Bonwell

& Eison, 1991) and the learning objectives of Bloom's taxonomy (Anderson & Krathwohl, 2001). This paper describes the design and delivery of the Problem Based Learning project which is focused on student centred learning where second year Electrical and Electronic Engineering (EEE) students are required to design and produce a product to promote STEM to the general public using their creativity.

Design/Method

Designing relevant engineering PBL projects to stimulate students' curiosity and independence in learning is fundamental in developing motivated and competent engineering graduates**.** Inspiring and motivating students through high-level communication, presentation and interpersonal skills is another significant challenge to engage students with poor English language background in the process of changing how they see themselves and preparing to be "engineers of 2020". The staff team has discussed how to design teaching activities and PBL projects to bridge the gap between theory and practice, and to create opportunities for students to develop not only strong technical skills, but also generic professional skills and satisfy the graduate attributes of both VU and Engineers Australia (EA).

Problems (projects) are at the very heart of the PBL paradigm. The assessment of PBL units focuses on the nature and quality of the learning process and the attainment of the learning outcomes. The engineering student population at VU includes a wide range of socio-cultural, linguistic and ethnic backgrounds. Over the years, English language proficiency levels have been noted to crucially affect engineering students' academic success. Poor command of English, sometimes with an extremely poor ability in both spoken and written English, is not uncommon. The seriousness of this matter is pronounced. Particularly as engineering educators and professional engineering bodies now emphasise as essential attributes of engineering graduates, not only lifelong learning but also "Effective oral and written communication in professional and lay domains" and "Effective team membership and team leadership" as stated in the Engineers Australia's Stage 1 Competency Standard for Professional Engineer (Engineers Australia, 2013).

The staff team has provided opportunities for students to build communication, teamwork, project management and reflection skills so that the social and nontechnical influences on engineering solutions and quality processes can be appreciated (Lattuca, Terenzini, Volkwein & Peterson, 2006). To support students' communication skills, the team has worked very closely with academic support staff to scaffold students according to their skills and abilities. Language and Communication workshops, team dynamics workshops, reflective practice workshops have been organised to support the diverse student cohort (over 60% of the second year EEE students enrolled in the PBL unit NEE2110 in semester 1, 2015 at VU were from NESB). Continuous feedback is provided throughout the semester to help students improve their written and spoken communication skills.

Reflection empowers students' self-development and enables them to be life-long learners. The staff team has introduced students to the concept of experiential learning integrated with reflection (King, 2002) to provide students with an opportunity to develop the seminal skills and take responsibility for their own learning (Dutton, 2003). It is believed that reflecting on one's actions and writing about them is a dynamic component in the whole learning process in the PBL learning environment. Students are encouraged to maintain a (private) project journal (logbook) which includes critical reflections and project management. Revisiting the journal allows students to see the connection between apparently unconnected areas, which leads them to a deeper understanding of the subject content of the learning (Kolmos & Kofoed, 2003).

Students are required to work in teams and use their creativity to design and produce a product to promote STEM to the general public. Students are required to demonstrate not only their learning outcome of the unit but also to show how their product can be used to raise community STEM awareness. For example, their products can be used to assist people with disability, to be showcased at outreach activities to the local communities and schools, and to be displayed on University open days. Students can explain the working principles of their products to the users so that the general public will appreciate the value of STEM and this can enhance STEM education via effective informal education.

Students were assessed based on their oral presentations, written technical report, project demonstration, and final written examination. The weightings of the assessment components are: 20% for two oral presentations; 20% for a team written project report; 10% for project demonstration and 50% for the end of semester examination.

Substantial feedback is provided over the semester, with the aim of improving the technical and communication skills of the students. For example, written feedback on the feasibility report which was a deliverable but not directly assessed. This gives the students an opportunity to receive feedback on their language and report writing skills without the pressure of assessment. Feedback on oral presentations is provided in the form of a Q&A session immediately following the presentation, as well as a rubric with written comments from each supervisor. Please note that the exam component is introduced so that students can be assessed appropriately for their technical and generic skills and their individual contribution to their team's work using peer assessment.

Students were also asked to reflect on their learning in this semester and comment on how they think they have improved their language and communication skills in both oral and written English, how they have collaborated effectively as an individual in diverse teams (with accountability for personal and team accomplishments), whether the project this semester has contributed to the development of their problem solving skills, critical thinking skills, analytical skills, and creativity.

Results

Student teams have proposed projects such as the User Friendly Wheelchair (UFW), the Movement Aid for the Vision Impaired (MAVI), Arduino Controlled Telescope Mount (ACTM), Home Security and Automation and Traffic Control System. Examples of the project descriptions extracted from students' technical reports are provided below.

User Friendly Wheelchair: "The purpose of the User Friendly Wheelchair (UFW) project is to give low-medium income feeble and elderly people the opportunity to remain mobile and independent. The UFW is designed for users who are unable to walk or travel for long distances. This allows users with limited mobility to move independently in their community. In addition, the project can help students to understand the processes and methods of scientific research and encourage students to advance their studies in their respective fields within social and practical contexts".

"The UFW is designed to be affordable and cost-effective. This enables people with a low budget, including elderly people and pensioners, to purchase it. The cost has been estimated at approximately $229 for each unit of the product. The UFW is moved via the means of an electric motor and navigational controls. It incorporates a range of features such as a Pulse Sensor, Proximity Sensors, a Liquid Crystal Display (LCD) screen and a joystick. It utilises two motors to power the main drive wheels and it is operated by the user through the joystick control. An LCD display allows the user to be visually informed with all the necessary information. The heart rate of the elderly person is measured by the Pulse Sensor. The

Proximity Sensors allow the user to maintain a safe distance from objects when they are not fully aware of their surroundings".

Movement Aid for the Vision Impaired (MAVI): "The MAVI cane is a simple and mainly mechanical device with built-in electronic device dedicated to detect static obstacles on the ground, uneven surfaces, holes and steps via simple tactile-force feedback. This is in the form of a walking stick with ultra-sonic sensors mounted to the middle and end of the walking stick that will face horizontally and vertically to detect objects in front of and below the person, such as walls and stairs. The aim is to provide more feedback to the visually impaired person warning them of objects before they run into them. In the event of an upcoming object, an audible alarm will be relayed to the person via headphones to warn them of the object. Along with the audible alarm, the handle of the cane is fitted with a vibrating module to give force feedback when an object is detected. The vibration frequency increases as the obstacle comes closer. This is useful when an audible alarm may not be audible on noisy streets. An LCD screen will also be incorporated into the design for calibration and setup purposes. All these systems will be integrated and controlled by an Arduino mega control processor".

Arduino Controlled Telescope Mount (ACTM): "The aim of this project is to design and build a product to promote Science, Technology, Engineering and Mathematics (STEM) to the general public. This is to be achieved by using the Arduino Mega 2650 board and the base kit provided with the board. As per this aim, the team come up with the idea for the Arduino Controlled Telescope Mount (ACTM)".

"The ACTM is a base structure to which a telescope or a camera can be attached. The use of either a camera or a telescope is interchangeable so only one may be referred to as an example. The ACTM would enable the user to focus their telescope on a specific astronomical location in the sky. This would enable them to view entities in the sky or take long exposure pictures. The focus of development on the ACTM is based on its use as a tool for astronomy and photography. The ACTM is controllable via a joystick for analogue input or an IR remote for a digital, more accurate targeting. Figure 1 illustrates a sketch of the ACTM system".

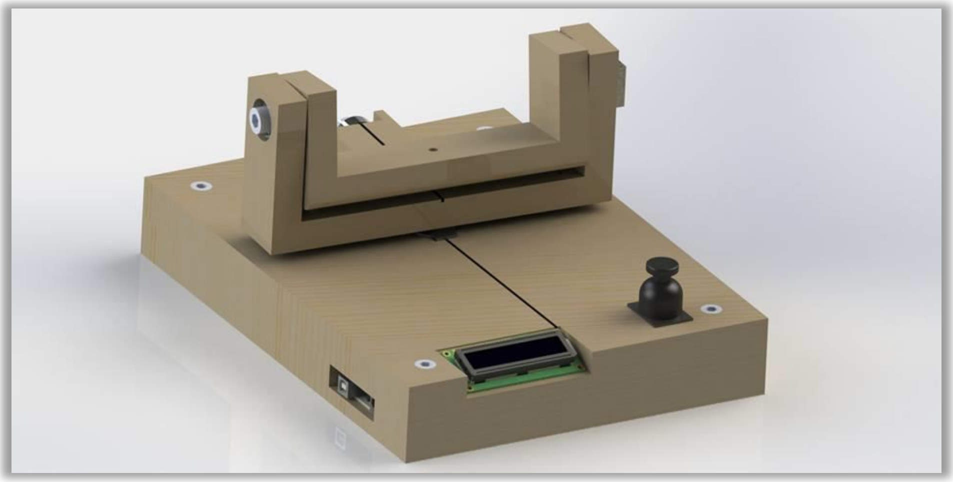

Figure 1: A sketch of the Arduino Controlled Telescope Mount (ACTM) system

Lectures, laboratories, language and communication classes have been conducted in addition to weekly team meetings and team/supervisor meeting to support the PBL learning activities. The assessment of PBL units focuses on the nature and quality of the learning process and the attainment of outcomes (Tien et. al, 2004).

Language and Communication Skills: The team has built assessment tasks linked directly to the development of students' communication skills. Students are given clear written instruction at the beginning of the semester on the structure and content of their technical feasibility report, technical report, and oral presentation along with the technical requirement of their project work. Language and communication (L&C) workshops such as technical feasibility report writing, technical report writing, and oral presentation preparation are organised and conducted systematically. Continuous feedback is provided through the semester engaging students to improve their written and spoken communication skills. For example, students were asked to write a technical report based on their PBL project two weeks before it is due. All technical supervisors of the PBL teams are required to review each team's draft technical report and provide feedback on the format, language use, logical development, quality of literature review, technical validity, and referencing styles of the paper and asked the team to modify the paper according to the feedback. Student teams are then required to rewrite their technical paper taking into account all feedback received before their final submission. A similar approach has been used for the development of students' oral presentation and technical report writing skills. The method used for the development of students' communication skills is appreciated by the students and the following quote is from students' reflections: *"My written English has improved due to editing technical and feasibility reports", "The oral presentations helped me develop my abilities in expressing new ideas more easily and more freely". "Weekly group meetings improved my communication skills significantly"."The oral presentations helped me improve my ability to control my nerves". "Self-assessment was very useful to make my writing more clear and coherent"*. More students' feedback on Language and Communication classes can be found in Table 1.

Table 1: Students' feedback on Language and Communication Classes

What worked well?	What could be improved?
• Team presentation and learning new skills • Reports went fairly good. • The explanations for how references worked and discussions in the class. • How to structure different reports. • Communication between team members. A lot of the class seemed involved in L&C sessions. The short duration of the sessions didn't tire students out at the end of the day. • The flexibility of the overall subject. The freedom of choice. The feedback provided helped to improve our reports. • Oral presentations and report work. • Teamwork, preparation/Oral presentation. • The way the class was conducted - lots of feedback, previous report templates, reference help. • Communication between group members and seeing finished reports. • Feasibility report writing and group work. • Nice studying environment and teaching style.	• Definitely my study outside of class, my group speaking skills, group members not plagiarising work. • Improve work done outside of class, leadership skills, team communication. • The time gap between classes. • More feedback on our individual work, more tutorials availability. • Leadership training, time management, goal setting (e.g. the Seven Habits of Highly Effective People) • Splitting the workload more evenly, enticing some students to attend more L&C classes. • Resources (for technical reasons). • Weekly reflective journals, assistance with finding resources. • Planning, reflective Journals. • Group work, team co-ordination, intellectual level of every member. • Learning habits, attention towards study, trash talking, time wastage. • Academic language for report, presentation, reflective journal • The structure of reflective writing i.e., what is needed to be done by when, the in-depth of references and report structure. • Organisation and preparation before team meetings.

Team Working Skills: Workshops on team formation and team dynamics have been conducted to introduce the concepts of Belbin's Self Perception Inventory for Team Role Assessment so that they can develop a deeper understanding of themselves and of others and hence work more effectively in a team.

The initial workshop consisted of three activities. The first activity was the description of a scenario of being stranded in a jungle and the students were asked to rank the participants in the situation. The students completed the task on an individual basis but discussed their answers in small groups and then had to reach a group consensus. Based on their ranking of the various characters, the students gained an insight into which personality characteristics they valued over others.

The second activity was an individual activity. The students were given a sheet which listed various words (e.g. creative, efficient, doubting, and unadventurous). The students had to tick the boxes next to the words which they felt described them the most and then transfer the results to another sheet. This sheet grouped the words they had ticked under the Belbin Group roles, for example, the Ideas Person, the Investigator and the Challenger. This, together with another sheet with related descriptors assisted them to gain an insight into what role they may play within a group work setting as well as the aspects of their personality which may contribute positively and negatively within a group work context. In the final activity the students were then asked to write their most frequently occurring characteristic on a slip of paper, and find other people in the room with varying dominant characteristics in order to form a diverse working group with strengths in different functionalities.

The students found the activities interesting but a lot of them had already decided on the people they would select for their team. The activities did raise the students' awareness of the strengths and weaknesses in their teams and how they may have to adjust their preferred working method to compensate for these weaknesses.

In the second workshop the students were asked to sit in their teams and draw up a group contract for how the group is going to function. Some of the topics covered were: expectations of individuals regarding team meetings, meeting individual and team deadlines, and the possible consequences if expectations are not met. The session was concluded with a discussion and the students' output used as the basis for a team contract that all individuals were required to sign.

The method used for the development of students' team working skills is also appreciated by the students and the following quote is from students' reflections *"Diversity in the team in terms of talents and skills had a positive impact allocating tasks to each team member". "Working in a team allowed me to become more motivated, more hardworking, and more organized". "Working in a team taught me how to meet the deadlines". "Our team had a good advantage of being diverse in terms of talents and skills, so that has tremendously impacted our work in a positive way allocating tasks that fit to each member's strength and abilities".*

Reflective Practice: A workshop on reflective practice was conducted in the middle of the semester. The students were shown the various levels of Bloom's Taxonomy and the fact that greater in-depth understanding and improvement in practice can only be achieved if the students actively undertake regular reflection. The students were presented with a sample reflective learning cycle (Kolb, 1984) which they could use to record observations, undertake reflection, perform analysis and determine the actions they need to take in order to improve their understanding on a regular basis. At the conclusion of the workshop the students were asked to answer specific questions in their next reflective journal entry so that they could begin implementing some of the ideas discussed in the workshop. This was called Reflection 1. The students were also asked to complete another reflection (Reflection 2) at the end of the semester.
The methods used have helped the students to identify weaknesses in their written

communication skills, time management skills, and team working skills with comments like *"I did not use enough references for my written documents". "I need to improve my time management". "By setting a high standard for the full potential of the project, we couldn't demonstrate the finished product. We had to disregard some parts due to time constraints. Better planning and preparation would help setting more realistic goals in the future". "Weekly report writing was very challenging because English was my second language. Therefore, I tried to write more and asked my language and communication teacher to read my writing and give me feedback on it". "The oral presentations were the most difficult aspects of this unit. However, this helped me gain a lot of confidence and improve my public speaking abilities". "We should have been more focused on the primary goal of the project which was to manage our time such that we could finish the product for the oral presentation". "Since we split the programming part between the team members, we experienced some difficulties combining the final codes. Regular communication with the team members during the programming stage would have resolved this issue"*.

Figure 2 shows the Student Evaluation of Unit (SEU) survey result for the unit. Eleven out of thirty-three students who enrolled in the unit have completed the survey. It can be seen from Figure 2 that the responses to all 11 questions are consistently higher than the College and University average.

Conclusions

Overall, the way the unit has been run has been appreciated by the students and the feedback from the students is very positive with comments like *"What I liked about this PBL was the freedom to choose a project. This allowed us to come up with a good solution out of the many possibilities". "The fact that this unit was very 'hands-on' was very helpful. This helped us learn how to research for a solution and implement in practice". "Tutorial classes and regular meetings with our supervisor helped me learn a lot of new things". "I found the laboratory and team meetings very useful".*

Some of the teams have produced proto-type products which can be used to assist people with disability and be used to offer outreach activities to the local communities and schools, and also be used on University open days. Many students feel very proud that they can use their own creativity to potentially develop useful products to assist elderly and frail people in the community and promote STEM to the general public at the same time. The students' creative design product will promote STEM, help the general public to have a better understanding of STEM, its methods and processes, and encourage students in primary and secondary schools for advanced study in STEM.

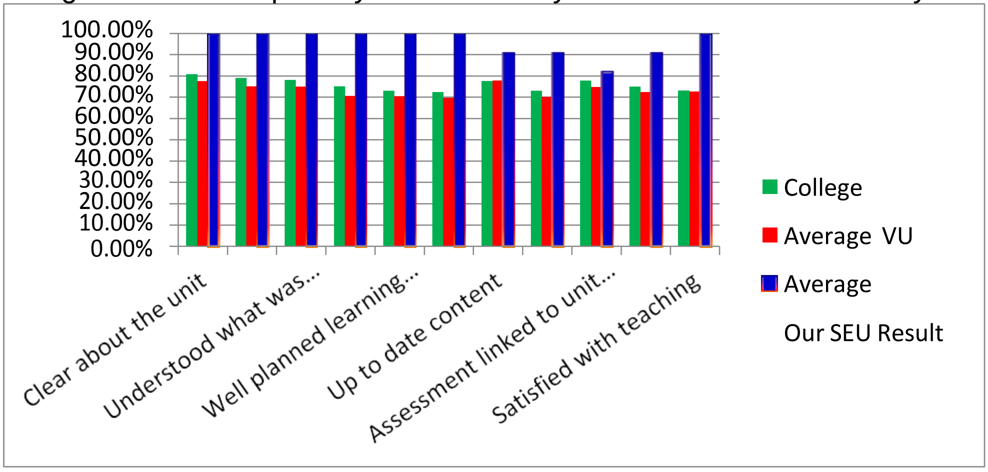

Figure 2: Comparison of Second Year EEE PBL Unit NEE2110 Student Evaluation of Unit (SEU) result with the College of Engineering & Science and VU average

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