Inspiring and stimulating students to learn mechatronics (robotics) through authentic projects and co-curricular activities

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Structured Abstract

BACKGROUND

Mechatronics is a relatively new discipline of engineering that is fast gaining in popularity. It provides the synergistic fusion of mechanics, electronics, control theory, and computer science. Authentic projects focus on real-world, complex problems and their solutions using problem-based activities (Lombardi, 2007). The dual goals of deeper knowledge of technical fundamentals and the ability to lead in creation and operation may be achieved through a curriculum structure that exploits extra- and co-curricular and extra-campus learning opportunities (Crawley, 2007).

PURPOSE

The mechatronics engineering subjects are in general thought as challenging to learn and hence they need innovative approaches to impart knowledge while keeping students' interest. Therefore, purpose of this study is to stimulate student learning through authentic projects while enhancing the student engagement and deeper learning through co-curricular activities. The hypothesis is that the authentic projects and co-curricular activities can positively influence the students' learning and their current and future endeavours.

DESIGN/METHOD

An authentic project was introduced in a mechatronics subject. Students in the same subject were encouraged to participate in an international robotic competition which is of similar nature to the authentic project. They were also motivated to form the UTS robotic society for engaging in various other mechatronics/robotics projects. Feedbacks from the students were collected through the centrally conducted student feedback survey (SFS) as well as testimonies from the past and current undergraduate students.

RESULTS

The preliminary study shows that the authentic projects and co-curricular activities have positively affected the students' learning and current and future endeavours. Student feedback suggests that the external competition contributed to deeper learning of the subject matter. The UTS robotics society activities have stimulated the student learning and contributed to enhanced student engagement and learning opportunities which are self-driven based on individual interests.

CONCLUSIONS

Students' interest, engagement and deeper learning of the subject matter can be enhanced by authentic projects facilitated by carefully chosen co-curricular activities in mechatronics engineering discipline.

KEYWORDS

Authentic projects, co-curricular activities, mechatronics education

Introduction

Mechatronics is a relatively new and popular discipline in engineering. It provides the synergistic fusion of mechanics, electronics, control theory, and computer science. Mechatronics 2 is a stage 7 field of practice subject in the University of Technology, Sydney (UTS) with student numbers ranging from 30 to 60 in each semester. This subject aims to provide competence in the design and implementation of microprocessor-based products. Microprocessors are used in virtually every modern-day products including, phones, washing machines, refrigerators,… etc., as well as in many industrial engineering applications. Therefore, it is an area of paramount importance for today's and future engineering.

Mechatronics is a challenging area of study yet inherent with appealing applications. These fascinating applications can be incorporated in teaching the concepts by means of authentic projects. *Authentic learning typically focuses on real-world, complex problems and their solutions, using role-playing exercises, problem-based activities, case studies, and participation in virtual communities of practice* (Lombardi, 2007). The students often prefer 'doing' rather than 'listening'. Most educators also think 'leaning-by-doing' is one of the most effective ways of learning. However, these concepts have not been tremendously successful due to practical feasibility. For example, learning about earthquakes with authentic projects is far from real. On the other hand, learning about deep water creatures is feasible through visiting the sites but costly. This is not to argue that authentic projects cannot be applied in practice, but to argue that it is domain dependant. For example, visualization and haptic devices can be effectively used to help the learners feel the force and pressure to build their mental models of invisible factors such as intangible force fields (Bertoline, 2007). Robotics or mechatronics engineering is another discipline where authentic projects are feasible and appropriate to apply (Dagdilelis, 2005, Erwin, 2000, Isela, 2007, Mikropoulos, 2008).

The dual goals of deeper knowledge of technical fundamentals and the ability to lead in creation and operation may be achieved through a curriculum structure that exploits extra- and co-curricular and extra-campus learning opportunities (Crawley, 2007). These activities could be led by peers, and it is a well- established fact that the peers support make positive impact to improve students' confidence in their ability to succeed in higher education (Treisman, 1980). This is the fundamental idea behind the Michigan state university's CoRe experience programme (Walton, 2013).

This paper reports the use of authentic projects and co-curricular activities to stimulate students to learn mechatronics (robotics).

Data collection

The data collection was planned as a full-fledged formal survey and open ended descriptive questionnaires. The student feedback survey (SFS) at University of Technology, Sydney is a centrally managed primary mechanism for collecting student feedback on subjects and teaching of the subjects. The Vice Chancellor's directive on SFS mandates the use of SFS in regular monitoring of subject quality and evaluation of teaching across the university. The directive states that all subjects need to be surveyed via the SFS at least once every year, preferably at each instance. The SFS is completely anonymous and consists of 9 evaluation statements and two open ended questions[1]. It also allows incorporating new questions of any aspects of the subject. The SFS results presented in this paper is based on the SFS results received for the Mechatronics 2 subject over the years: 2008 to 2014. The student testimonies supporting the co-curricular activities are received from an open survey conducted by the author. The questionnaire was sent to the Robotic Society members and

[1] http://www.pqu.uts.edu.au/tracking-performance/student-surveys/student-feedback-survey.html

competition participants. It was completely voluntary and avoided any influence in completing the questionnaire. The survey questionnaire is,

- In your opinion, how much Robotics Society activities have contributed to your learning of Mechatronics?
- Did it motivate and inspire you to continuously progress in Mechatronics?
- What is your rough average effort put into your Robotic Society activities (Hours/week)?
- In your opinion, how much NI ARC has contributed to your learning of Mechatronics?
- Did it motivate and inspire you to continuously progress in Mechatronics?
- What is your rough average effort put into the competition (Hours/week)?

Influencing and stimulating student learning through authentic projects

Microprocessors are used in virtually every modern-day products including phones, washing machines and refrigerators, as well as in many industrial engineering applications. In the Mechatronics 2 subject at UTS, students gain a detailed understanding of the software and hardware architectures of a typical modern microprocessor-based system, and develop hands-on experience in mechatronics product design. They learn about sensors, actuators, system integration, microprocessor-based control and path planning algorithms.

Introduction of an authentic project

Prior to 2005, Mechatronics 2 included a large robot design project, however the students did not appreciate its real world application. As the incoming subject coordinator in 2005, an authentic project was created to simulate a real-life ‘search and rescue’ scenario, where a robot needs to autonomously navigate a maze (*disaster zone*) without bumping into walls; find an infrared source (*victim*); return to the start (*command centre*) through the shortest path in the minimum time; and produce a geometric map that includes the location of the infrared source (*victim*). This task requires complex real-world problem solving, software/algorithmic development and effective team work. The authentic project has stimulated the students’ interest as reflected in the SFS surveys,

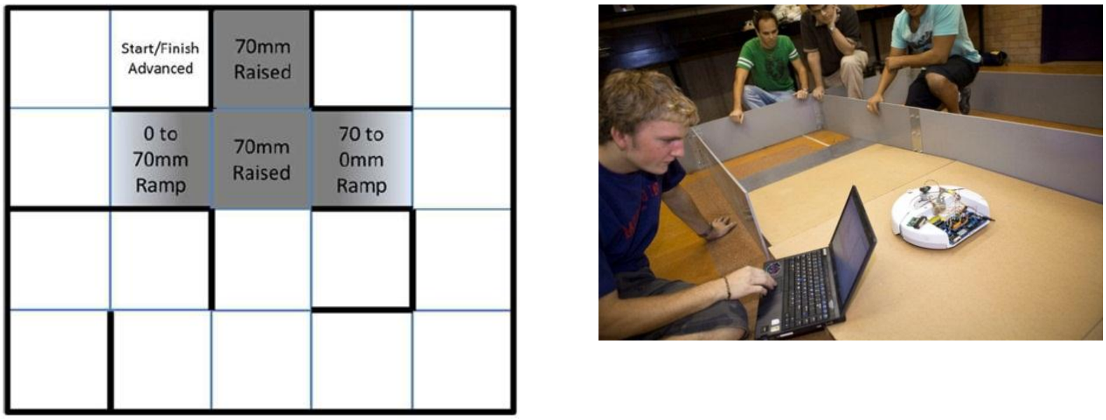
- *Very interesting. Great subject content. I have massively enjoyed the work.* (Spring 2008)
- *Being a mechatronics student, I enjoyed this subject in the sense that it was very relevant to the mechatronics major.* (2009 Spring)
- *The practical assignments encourage learning very well.* (2014 Autumn)

Milestone based assessments

Students’ feedback collected through reflective conversations indicated that they lacked the experience to deal with larger projects involving software/hardware designs. It was evaluated and responded to the gap in assumed knowledge by restructuring the large project into four milestone assessments.

The first three assessments are formative and focus on developing capabilities in software development for controlling, sensing and system integration which are essential for the fourth assessment. The students are given two weeks to complete each of these assessments. Once completed, oral feedback is given focussing on the intellectual understanding that is required for the fourth assessment. The fourth assessment is introduced as a ‘competition’ for the best search and rescue scenario to stimulate the students.

The maze was given in advance with the starting and stopping position (see Figure 1 (a)). The challenge is to explore the maze without colliding with walls until an infra-red source (location unspecified) is detected. Once it is detected, the robot needs to return to the starting point through the shortest path. This requires efficient path planning and memorizing the visited parts of the map. This needs to happen at the fastest speed to win the challenge. The competition was made more challenging by adding an elevated platform within the maze, so the robot needs to detect a cliff and avoid falling from it (see Figure 1 (b) for the section of the raised ramp in the maze). Further a virtual wall in terms of an infra-red curtain was placed in an undisclosed location. This challenge was taken very well by some student groups however, the feedback received suggested that some other student groups had difficulties in managing it. They were overwhelmed by the complexity and in some cases it was looked as a discouragement. Therefore, the competition was revised to have two challenges. One is the more complex task called “advanced maze” which was described above. It attracts higher marks. The second challenge was designed as “basic maze”, which is on a simplified version of the maze without cliffs. It attracts lower marks. The groups were given two attempts with the option of attempting either challenge. The students use this option to strategically plan for the competition depending on their capabilities and also to maximize their chances of getting higher marks. For example, in the past, some groups attempted both advanced maze and the basic maze in the two attempts while some groups opted to attempt advanced maze two times. In either case, the higher marks received is considered as the final mark.



(a) Maze used in the project

(b) Mechatronics 2 students are working on the project (raised ramp section of the maze)

Figure 1: Maze and its use in the mechatronics 2 project

The marking criteria for the fourth assessment are given well in advance and are based on the effectiveness of the solution reached in the search and rescue scenario. The learning outcomes are assessed based on performance in the competition, a final report and a presentation. The final report reflects students’ learning experience, their critical analysis of the results and rationale for decisions made in the project. The group presentation demonstrates combined intellectual rigour. Each group provides a video explaining their approach and system capabilities (as shown in this clip: www.youtube.com/watch?v=JYXb7c4IYW4). Immediate oral feedback is given to the students by means of questioning and constructive criticisms.

To further the accessibility of the subject, some of the lecture and lab sessions were converted into student help sessions, and inquiry-based learning was introduced by proactively approaching the student groups and asking open questions to help them work through the problems. A student discussion forum was created on UTSOnline to bolster group conversation, and this has positively affected the students and provided us with valuable feedback about their challenges.

The SFS results support students’ positive perception about the milestone based assessments, which is reflected in the following testimonies.

- What did you like particularly in this subject? *Structure of assignments*… (Spring 2009)
- *There were a lot of assessments that lead to the final one so you were constantly working towards it*. (Spring 2012)

Filling gaps in assumed knowledge

A student survey (separate to SFS) was conducted in 2008 to identify general difficulties of learning the subject, which alarmingly showed that students were unable to program in the C language, which is essential for the Mechatronics 2 robotic project. To address this gap in assumed knowledge a C programming introductory session within the subject was introduced. This session is targeted at introducing preliminary C programming concepts and hands on use of it in microcontroller programming. After this introduction, the SFS results improved significantly (by almost an entire point) as: The SFS results for the *" My learning experiences in the subject were interesting and thought provoking"* has improved from 3.38 (in 2008) to 4.2 (in 2009) in a five scale: 1 – Strongly Disagree, 2 – Disagree, 3 – Neutral, 4 – Agree, 5 – Strongly Agree. Further, some student testimonies from SFS about this initiative,

- Student quote to the question, What did you like particularly in this subject? *The inclusion of tutorials regarding C programming with the microchip over last year's version of class*". (2009 Spring)
- *C programming is something that many mechatronics engineers will likely come across in the workforce*…..". (2011 Spring)

Linking with another prerequisite subject

Mechatronics 1 is a prerequisite for Mechatronics 2. In Mechatronics 1 students fabricate and test a PIC microcontroller board (the circuit board shown in Figure 2 (b)) from the electronic components (as in Figure 2 (a)). However, prior to 2007, the students used different types of microcontrollers in the Mechatronics 2 project and therefore, the students could not see the link between the two subjects. In order to improve the links between subjects and to show a practical use of the board introduced in Mechatronics 1, the Mechatronics 2 assessments were redeveloped to integrate the same PIC microcontroller board. The strategy was proven to be successful. In the process, a professionally made maze structure and the iRobot Create® were also introduced (see Figure 1 (b) and Figure 2 (b)). Twenty four hour access was given to the maze area to enhance the flexibility of resource usage. This was very helpful as the students could meet and work together without having to worry about time table clashes and work commitments. Following student testimony shows student perception about the change.

"….*Content was Interesting and VERY relevant. Added to the end of Mechatronics 1 (48622) very well*……." (2011 Spring)

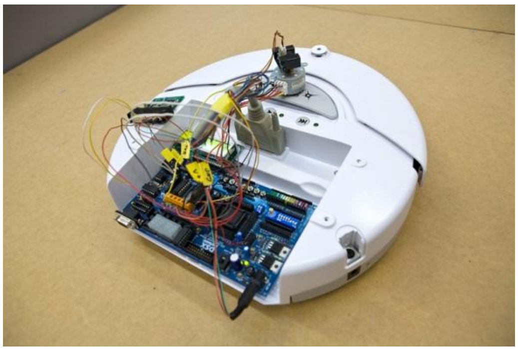
Feedback from the former graduates

Feedback was collected among former graduates of the Mechatronics course at UTS to assess the impact of Mechatronics 2 on their current and future endeavours. This feedback was voluntary and no influence was made in the process. Following are some student testimonies.

- *Looking back I recognise that the subject Mechatronics 2 had quite a lot to do with where my career has ended up … Mechatronics 2 was my first hands-on experience with developing a complete mechatronic system*. (recent UTS PhD graduate in the field of robotics)

- *It [Mechatronics 2] was also our first real opportunity to work on a robotics project … I really enjoyed this experience and it increased my interest in robotics, both as a hobby and as an area for further study: Mechatronics 2 helped to inspire me to go on to work towards a graduate degree in robots, and gave me important skills which I have drawn on during the graduate work*. (final stage UTS PhD student in the field of robotics)
- *My passion is robotics – largely shaped by Mechatronics 2.... As a result of this passion, I have relocated to the UK to pursue employment in the robotics innovation division of Dyson where I hope to strongly draw on the fundamental learning I developed through Mechatronics 2*. (UTS graduate)
- *Mechatronics 2 is one of a handful of subjects which is absolutely useful, interesting and challenging. I believe the Mechatronics 2 subject provides a solid basis and helps to develop useful real-world skills*… (senior mechatronics engineer and former graduate of UTS)

(a) PIC microcontroller components for the board development in Mechatronics 1



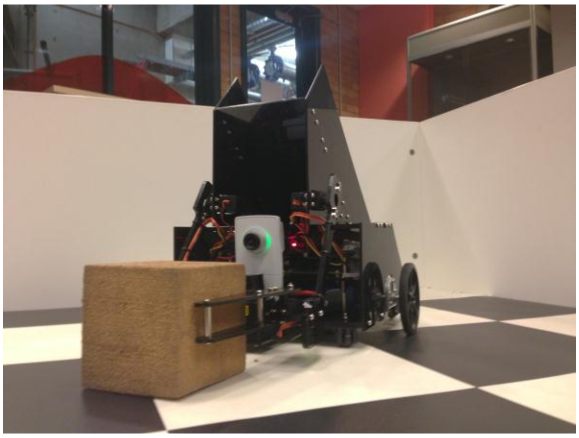
(b) The robotic platform with the PIC microcontroller board used in the Mechatronics 2

Figure 2: Linking two subjects through hardware development and application

Enhancing student engagement through a co-curricular activity: International robotic competition

The dual goals of deeper knowledge of technical fundamentals and the ability to lead in creation and operation can be achieved through a curriculum structure that exploits extra- and co-curricular and extra-campus learning opportunities (Crawley, 2007).

Team



Robot

Figure 3. The team and the robot

National Instruments Australia (NI) organised an autonomous robotics competition (NI ARC) in 2011, which had some similarities to the Mechatronics 2 competition in many aspects.

Recognising this as an enormous opportunity for our undergraduate students to expand their robotics experience, this competition was discussed in the Mechatronics 2 class. The students were motivated to participate. The initial funding that was required for the development of the initiative was secured through various means: hardware/software support to the value of $27K was provided by National Instruments Australia, $1K was provided by the Faculty's Associate Dean (External Engagement) and another $750 was provided by the Centre for Autonomous Systems at UTS. A lab space was negotiated and secured to have 24/7 access for the students to work continuously on the project. Students have been enthusiastically participating in the NI ARC since 2011, despite the fact that there is no academic credit. The competition scope changes every year, however it is varying around building a robot (within constrained dimensions) which can autonomously navigate, detect and avoid obstacles, pick a particular object and place it on an specified location, and achieving the tasks in the fastest time. It can be looked as a more complicated version of the Mechatronics 2 project. In 2013, UTS students won the 'Best Robot Design' award in Melbourne, defeating 16 other universities in Australia and New Zealand. The students perceive the opportunity to participate in such competitions are interesting, informative and enhance their skills that are not possible to achieve in academic classroom settings. Following is a testimony in support of the co-curricular activity:

> *NI ARC has been responsible for advancing my theoretical knowledge obtained throughout the mechatronic course and applying it to real world applications. … The competition also provided an opportunity for developing project management skills [and] … leadership skills.* (senior undergraduate student who participated in NI ARC over three consecutive years)

Enhancing student engagement through a co-curricular activity: Robotics Society

Soon after the competition in 2011, a retreat was organized to discuss the students' experiences. The competition was generally described by the students as a fantastic learning experience. Therefore, they were inspired to form the "UTS Robotics Society" (RoboSoc), which allows the students to continuously participate in such competitions and work on robotic projects. The students have been advised for strategic directions and on the society activities. RoboSoc has grown since then to 32 active members who meet weekly for project work. The RoboSoc offers the chance to participate in six different mechatronics (robotics) projects. Some of them are catered for beginners and others are for robot enthusiasts who have previous experiences. They also run workshops for the beginners to enhance their interests and knowledge. The society is currently planning their own competition, 'Zumo bot', to maintain members' interest. The influence, stimulation and motivation of RoboSoc activities for enhanced learning are reflected in the two testimonies given below.

> *In my opinion the Robotics Society has complemented my learning at UTS, motivated my studies and taught me valuable mechatronic skills that I could only get through experiences such as it. Thanks to the initiative and support from Dr Kodagoda, I was given project opportunities as a young undergraduate engineer that I would not have been given until entering the workforce. … When talking with employers, they have been very impressed with the opportunities given to students at University of technology, Sydney and the exposure to tasks and projects such as the Robotics Society. I have been told that it has improved my employability significantly as an engineering student*. (senior undergraduate student and the inaugural president of RoboSoc)

> *The intensive learning experience of that competition [NI ARC] proved valuable enough that we wished to continue our involvement with practical robotics, which led to our formation of the UTS Robotics Society, again with much input from Dr Kodagoda. It is likely that without that initial exposure to the competition, and Dr Kodagoda's continuing*

support, the Robotics Society would not exist … Overall, through the NI ARC competition and the Robotics Society, being part of a diverse community of people who share an interest in robotics has been a constant source of motivation and inspiration to continue my own education in the field. (senior undergraduate student and an inaugural member of the RoboSoc)

Discussion

Introduction of authentic projects and relating it to two co-curricular activities in Mechatronics engineering discipline is not coherently addressed in the literature and this paper presents preliminary results. The SFS is a university across centrally conducted student feedback survey. SFS of the Mechatronics 2 subject over the years clearly show the authentic project and milestone based assessments have motivate the students and they are highly appreciated by the students. The students also appreciate the introduction of the C language component to fill the gaps in the assumed knowledge and linking with the pre requisite subject. The student testimonies for the co-curricular activities are based on a survey conducted by the author. Although, it was not anonymous, the students were not influenced and completely voluntarily responded. The responses highlight the significance of the activities and their influence on motivating and inspiring them to do robotics (Mechatronics).

Conclusions

Mechatronics engineering is a relatively challenging field for students in engineering. It has many interesting practical applications and therefore it is possible to utilize authentic projects in stimulating student learning. It is also a fascinating area where co-curricular activities can be organized to enhance deeper understanding through peer engagement. This work reports integration of authentic projects and co-curricular activities in a mechatronics subject offered at UTS. The authentic projects stimulated the students' interests and Mechatronics 2 significantly contributed to the students' current and future endeavours. The preliminary analysis of student feedback suggests that the external competition contributed to deeper learning of the subject matter and the UTS robotics society activities have stimulated the students and contributed to enhanced student engagement and learning opportunities which are self-driven based on individual interests. The student feedbacks also suggest that the authentic projects and co-curricular activities can positively influence the students' learning and their current and future endeavours. These outcomes are based on the preliminary results and it is intended to conduct an anonymous formal survey with a larger number of subjects in the near future to solidify the outcomes. Therefore, strategies to get more students involved in co-curricular activities are to be investigated and those serve as the future direction of this work. Further, some issues raised by the students are still in consideration. The whole project component contributes to maximum of 50% of the final marks of the subject. Some students' feedbacks reflect that the 50% is not reasonable given the amount of effort put in achieving the assessments. Fairness of the individual evaluation in a group setting also needs more attention and are served as future directions.

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