Application of project based learning in advanced dynamics

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ABSTRACT

This study focuses on the engineering program at CQUniversity, Australia that employs project based learning approach in undergraduate engineering course. The project based learning technique in engineering education is intended to expose students to something similar to real life as a professional engineer. This study provides a brief description of project based learning taking as a case study that involves the students' project in a group, requiring problem solving, decision making, investigative skills and reflection. The project includes teacher facilitation only rather than the teacher stipulating solutions. It is found from this study that the students can practice new learning habits through project based learning. With project based learning, students can think in original ways to devise solutions to real world problems and also students can acquire creative thinking skills by showing that there are many ways to solve the problem. The paper focuses on the framework of the course and the expected outcome of the course and presents the experiences in using project based learning in an engineering course of advanced dynamics (of a mechanical system) and also discusses the effectiveness of project based learning in contrast with traditional based approach.

Keywords: *Project based learning, traditional based learning, mechanical system*

INTRODUCTION

The project based learning (PBL) technique is an approach to engineering education. PBL is a process that engages learners in carrying out their project with a manner which ideally relates to their interests. Learning methods and supporting informational materials in the higher education can be enhanced for varying disciplines by engaging students to unravel real life problems through project based investigation (Ashfaque *et. al.*, 2010)

The PBL incorporates the subject areas within a program by means of realistic problems. Students also achieve some core generic skills through PBL, which are considered as follows:

- Students work in a team which promotes students' ability to recognise their role as members of a team
- Encouraging students' awareness of what?
- Developing students' design skills
- Developing students' systems thinking approach
- Developing students' own research capabilities and other work-based skills
- Improving students' ability to collect and critically analyse information in order to make sound judgement and evaluate their progress through performance of tasks and achieve final outcome
- Developing students' problem identification and solving abilities.

PBL is a useful approach to instruction that can be used in conjunction with other approaches. Teachers who make extensive use of PBL unite a number of educational ideas, each supported by significant research. Lenschow (1998) suggested that a small case trial-and-error PBL approach could be applied before moving to a large-scale PBL project. This attempt will help teachers to understand the real challenges of PBL. In PBL, projects should have given to the students in personal and groups' levels in which students could use their thinking, problem solving, and creativity skills **(**Zdener and Zoban 2004).

Fosnot (1999) clarified that constructivism is an extensively used educational theory that lies on the idea that students create their own knowledge in the basis of their own experience. Constructivism focuses on students being animatedly engaged in implementing their knowledge to finish a project rather than inactively engaged in receiving the teacher's knowledge. PBL can be cited as one approach to creating learning environments in which students create personal knowledge.

Gardner (1995) discussed the theory of multiple intelligences that each person has a number of different types of intelligence and these various intelligences can be achieved through an appropriate training and experience. The use of PBL is one approach that increases each person's multiple intelligences and each person can develop his or her own individual potentials. David Perkins (1992) analysed different educational theories and approaches and he strongly supported the theory of multiple intelligences of Gardner. He also suggested in his study that education can be considerably improved by more definite and appropriate teaching for transfer, concentrating on higher-order cognitive skills, and the use of PBL.

PBL provides an authentic environment in which teachers can facilitate students increasing their skills in cooperative learning and collaborative problem solving. *"Project-based learning frequently includes teams of students engaged in cooperative learning and collaborative problem solving as they work to complete a project. Cooperative learning has been shown to be effective in improving academic and social skills; however, successful cooperative learning requires careful organization and sometimes explicit training in collaboration and communication (Graumann, 1993; Johnson, 1986)"*.

Therefore it is evident from the past literature that, if well implemented, this approach is an effective tool for engineering education and the student's learning process can be improved by involving them in the education process and students' participation can be facilitated by introducing the innovative technique in an attractive manner.

PBL is playing a key role in the enhancement of student participation in CQUniversity. CQUniversity offers a variety of engineering courses using a PBL approach in every term. PBL approaches are now becoming more comprehensive and a popular platform in engineering education at CQUniversity due to its unique strategy and by student demand. This paper provides an analysis of the PBL approach in "Mechanical Systems" as an example in comparison with a traditional approach to teaching.

STUDENT BENEFITS OF STUDYING PROJECT BASED LEARNING APPROACH

Traditional teaching approaches mainly concentrate on verbal or linguistic and mathematical or logical intelligences alone (Gardner, 1995). This can create frustration for students who are less comfortable with traditional learning**.** PBL is a method of activity that highlights learning activities and this approach is generally less structured than a traditional approach. Moreover, students often must organize their own work and manage their own time in a PBL course. Students collaborate, and work together with fellow students to make sense within this PBL course work. Project-based instruction varies from inquiry-based activity by its emphasis on collaborative learning. Furthermore, project-based instruction differs from traditional inquiry by its accentuation on students' own work to represent what is being learned. Thomas (2000) explained the positive side effects of project based learning for students as they develop the positive attitudes toward their learning process, work routines, abilities on problem-solving, and self-esteem by using PBL.

PBL allows the teacher to incorporate various teaching and learning strategies and it assists learners in developing all of their intelligences. In a PBL course, the teacher is responsible to offer ideas and clarify how the project will progress rather than stipulating solutions (Johnson and Johnson, 1989). PBL is both a curriculum and a process. The curriculum consists of vigilantly selected and designed problems that demand from the learner acquisition of critical knowledge, problem solving competence, self-directed learning strategies, and team participation skills. The process uses a systemic approach to resolving problems or meeting challenges as encountered in life and career.

PBL permits teachers to create tasks whose intricacy and authenticity imitate problems in the real world. Preuss (2002) noticed that when students finish their projects, they are able to think contemplatively on their experiences about PBL processes. Moreover, students could distinguish the similarities between what they are learning and what is going on outside the institutions. Students can see the interdisciplinary nature of these tasks and see that each task may have more than one solution. Projects that have complexity will challenge students and stimulate them towards explore of innovative knowledge. They will achieve problem-solving, communication, collaboration, planning, and self-evaluation skills. Students should be asked to create a self-evaluation of the project after finishing a project which facilitates the students to focus on their learning process and allows them to see their progress. Self-evaluation gives students a sense of success and further inspires them for learning. Learners who can distinguish the relation between projects and the real world will be more prompted to understand and solve the problem. PBL has the potential to enhance a student's feeling of responsibility and control their own learning efficiently. Students who are allowed to identify their own learning goals will be more engaged in learning.

A CASE STUDY MECHANIACL SYSTEM (ENEM: 13013)

Objectives

The objectives of this course are to

- Describe the behaviour and analysis of mechanical systems.
- Model and analyse mechanical systems and consider the nature of engineering assumptions and effects of uncertainty on analysis and modelling.
- Design and analyse mathematical models including non-linear models.
- Predict behaviour of mechanical systems with the use of SIMULINK software.
- Develop interpersonal and technical communication skills.
- Prepare professional documentation of problem solutions and project report.

Course Contents

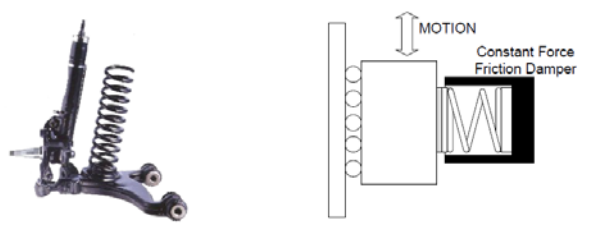
CQUniversity offers Mechanical Systems every year at term 2 (approximately from July to October) for the 3rd year undergraduate course of mechanical engineering. The course profile is designed and updated by Prof Colin Cole. The course has run for the last several years with efficiency. Projects, tutorial problems session, computer (MATLAB) lab session and laboratory sessions are main components of this course.

Projects

Four projects are distributed to the students working in teams during the term. Each team needs to submit one report and give a presentation on the submission date. Team membership is rotated throughout the term. Students are strongly advised to use peer assessment and personal timesheets to ensure their personal progress is satisfactory. Team work activities are assessed by the completion of survey forms by each member of the team and submitted with each project report. Forms are provided by the lecturer in standard check box format. The result of this survey is used to assist in determining individual students' grade. The projects in Term 2, 2010 are mainly focused on the different areas of mechanical vibratory and control systems and are as follows:

- Project 1: Mathematical models

This project involves a number of individual problems which could be split up and divided between the students in the group. 12 Figures associated with mechanical components and systems were normally considered as shown in Figure 1. For all cases, students are asked to consider the issues concerned with developing mathematical models and they require to introduce themselves to the alternate representations of equations available in the frequency domain (i.e. Laplace transforms).



<u>Figure 1: Mechanical components and systems</u>

- <u>Project 2: Single degree of freedom systems</u>

Analyse the performance of the motorbike as shown in Figure 2 was carried in project 2. In this project, students' analysis is to be limited to treating the motorbike as dynamic system with a single degree of freedom. Students are asked to analyse the same system using more complex models with increased degrees of freedom and other design/analysis issues as they arise.

Figure 2: The simple motorbike

- Project 3: Multiple degree of freedom systems

Project 3 was to improve the model that students already developed in Project 2 and again analyse the performance of motorbike shown in Figure 2.The first improvement in the model to be evaluated would be inclusion of the unsprung mass of the wheel, axles and the stiffness of the tyres assuming a typical tyre pressure of 0.2 MPa. Students are required to estimate an approximate linear model for the tyre stiffness. They are also asked to assume linear suspension elements again and analyse the two degree of freedom system clearly stating assumptions and limitations of their model, (Students require to use MATLAB).

The second improvement in the model to be evaluated would be inclusion of rotational degrees of freedom, then the addition of more translational degrees of freedom. Students were asked to estimate moments of inertia data as best as they possibly can from the diagram and mass data. The last part of the task would be to model the bike in Simulink and examine performance over a jump ramp as shown in Figure 3

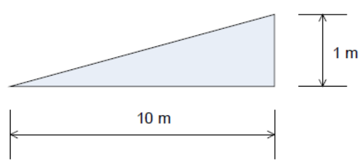


Figure 3: Jump ramp

- Project 4: Control systems

In project 4, students are asked to develop a drive line control for the monster truck as depicted in Figure 4. To reduce accidents, it is desired to have an automated control of the wheel stand sequence. Power is applied rapidly to just the rear axle until the front axle lifts off the ground and the truck makes an angle of about 45 degrees. The control system must hold the angle for about 5 seconds then let the truck dropped in a controlled way to the ground. The control must be robust and work with severe ground undulations and there is the possibility that it could be used for a jump initiated by a ramp profile as specified in Figure 3.

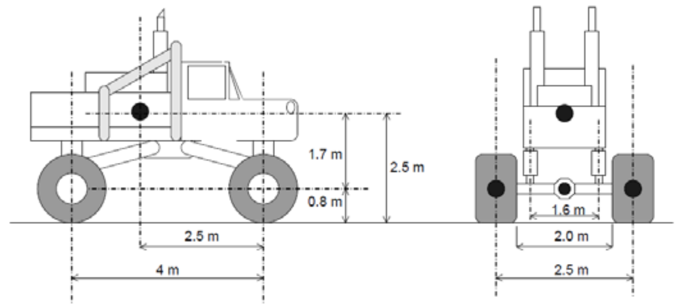


Figure 4: Monster Truck Stunt Control

The relevant data for this project is provided which is not included in this study. Centres of masses in Figure 4 refer to each mass separately. The centre of mass of the truck body does not include consideration of the axle and wheel assemblies. Students are requested to assume the power plant which is adequate for their needs.

Finally students are asked to develop a suitable P, PI, PD or PID controller in Simulink and demonstrate the robustness of the system with simulations of various scenarios and conditions and specify the required performance parameters, horsepower and torque of the power plant and drive train and also submit demonstration simulation results on severe undulations and negotiating the ramp from Figure 3.

Tutorial Problems Session

Tutorial problems are recommended for students to develop their mathematical skills. These should be submitted in their final portfolio. But there is no specific assessment item or percentage relating to tutorial problems alone. Tutors are mainly helping students as a facilitator to develop their mathematical skills and problems. At week 9, selections of demonstrated problems are distributed to the students. These problems are provided to assist students in demonstrating the learning outcomes.

Computer Laboratory Session

A major part of each project is the development of solutions, mathematical models and simulations that require some type of mathematical and/or modelling software. MATLAB/SIMULINK is used for this course. Students are encouraged to attend computer MATLAB session in every week during the term. In this session, students complete much of their project work. Projects require design, evaluate, and modify cycles along with the normal development of scripts (MATLAB) and simulation models (SIMULINK). Students are mainly driving their own task, but the teacher or tutor is available as a facilitator for helping students when they are stuck.

Laboratory Session

Students are recommended to do 5 laboratory sessions once in a week from week 3 to week 9 within a group. Laboratory sessions are focused on:

- Lab 1: Shaft whirling.
- Lab 2: Free vibrations with damping, logarithmic decrement.
- Lab 3: Forced vibrations with damping, resonance and beating.
- Lab 4: Torsional vibrations.
- Lab 5: Balancing of rotating systems.

Students can acquire practical knowledge of free, force and torsional vibratory and rotating systems through laboratory sessions. They also need to include their laboratory report in their final portfolio.

Outcomes of the Course

At the successful completion of this course, students should be able to:

Apply knowledge of core engineering science and mathematics to the modelling and analysis of mechanical systems.

- Explain the concepts and principles of control theory and apply control system approaches to vibratory and mechatronic systems.
- Explain the nature of engineering assumptions and uncertainty and the limitations of mathematical models and identify, evaluate and explain the consequences of assumptions made in analysis and modelling of mechanical systems.
- Design mathematical models with appropriate levels of complexity and select appropriate methods of analysis.
- Design appropriate non-linear models and evaluate and the system response using appropriate assumptions, models, solution techniques and simulation software.
- Relate theoretical development from this course to the problems of introducing operating and maintaining mechanical systems in the industrial context.
- Work and learn productivity, both independently and collaboratively to complete projects in a professional manner.
- Communicate effectively using mechanical systems terminology, symbols and diagrams and professionally document calculations and problem solutions.

ASSESSMENT CRITERIA

All students are required to submit their final portfolio for the final assessment at the end of the semester. Students must demonstrate their contribution to the project's completion and quality and what they have learned from the technical content of projects and by the processes involved in completing the projects and demonstrated analysis in the their portfolios. Students must demonstrate in their portfolio how the learning outcomes have been achieved through the completion of the projects. A brief discussion of the assessment criteria is presented here.

Projects

A grade is given for projects using criteria in Table 1 but this grade is not used directly in individual student assessment.

Table 1: Project Feedback Criteria

Grade	Criteria
High Distinction	Excellent technical content of projects Excellent reporting and presentation of project Comprehensive and thorough completion of projects Delivery of projects by due dates without extensions
Distinction	Good technical content of projects Good reporting and presentation of projects Completion of projects Delivery of projects by due dates without extensions
Credit	Sound technical content of projects – some errors Sound reporting and presentation of projects Completion of projects Delivery of projects by due dates without extensions
Pass	Passable technical content of projects – some errors Passable reporting and presentation of projects Completion of projects Delivery of projects by due dates within extensions granted

Portfolios

- General

  The portfolio is the full record of the student's journey through this course. It should include all notes, theory development, worked examples, demonstration problems, laboratory sessions notes and workings, explorations in design, management and team issues and reflective journal.

  The portfolio is used to assess the student's increase in knowledge, effective management of him/herself and others, team work, communication, commitment and learning processes.

  Selections of problems are distributed to the students at week 9. These problems are provided to help students in demonstrating the learning outcomes.

  - Reflective journal and personal management

  In the reflective journal section of the portfolio, students are used to reflect on what they have set out to learn, how they have approached their learning, what they have achieved and what they would do differently in future to improve their learning effectiveness.

The final grade is awarded to each student by the lecturer using criteria based assessment process in accordance with the criteria schedule which is illustrated in Table 2. The award of grade is dependent on (i) delivery of the projects; (ii) the student's demonstrated achievement of the learning outcomes of the course, (iii) the student's commitment to the team and (iv)the holistic development of each student.

Table 2: Portfolio Assessment Criteria.

Grade	Criteria

High Distinction	Students demonstrated contribution to: --Excellence in technical content of projects --Excellence reporting and presentation of project --Comprehensive and thorough completion of projects --Delivery of projects by due dates without extensions --Student understands and can apply principles to new areas and derive new innovations --Student can explain almost all content --Student knows the content and is able to transfer or apply it to large complex problems --Student shows competency in completing 75% of Demonstrating Problems --Student demonstrates excellent professional ability and attitude
Distinction	Students demonstrated contribution to: --Good technical content of projects --Good reporting and presenting of projects --Completion of projects --Delivery of projects by due dates without extensions --Student understands content and can apply principles to new areas --Students can explain almost all content --Student knows the content and is able to transfer or apply it to some difficult problems --Student shows competency in completing 50% of Demonstrating Problems --Student demonstrate excellent professional ability and attitude
Credit	Students demonstrated contribution to: --Sound technical content of projects – some errors --Sound reporting and presenting of projects --Completion of projects --Delivery of projects by due dates without extensions --Student understands declaratively --Students can discuss almost all content meaningfully --Student knows the content and is able to transfer or apply it to typical problems --Student shows competency in completing 25% of Demonstrating Problems --Student demonstrate creditable professional ability and attitude

Pass	Students demonstrated contribution to: --passable technical content of projects – some errors --Passable reporting and presenting of projects --Completion of projects --Delivery of projects by due dates without extensions --Student understands declaratively --Students can discuss 75% of the content meaningfully --Student knows about the content and is able to transfer or apply it to typical problems --Student demonstrates acceptable professional ability and attitude

CONCLUSION

Project-based learning is a well-established component of the educational system and pedagogy of CQUniversity in engineering education. The course "Mechanical Systems" is an ideal example of PBL course in advanced dynamics. It helps students learn to carry out reliable, multidisciplinary tasks in which they plan their time, make effective use of limited resources and work with other students. Students drive their course where teachers or tutors are working together with the students as a facilitator. In addition to these, the PBL approach encourages students to gain individual program learning outcomes. These outcomes are expressed in terms of knowledge and understanding, logical skills, practical and subject-specific skills and exchangeable skills.

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