An innovative delivery and assessment of Thermofluid Engineering: a PBL course in undergraduate engineering program

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Abstract: *The intent of project based learning (PBL) in undergraduate engineering courses at CQUniversity is to expose students to real life engineering problems. Delivering Thermofluid Engineering as a PBL course aims to facilitate students developing and demonstrating mastery of technical skills required for analysis, formulation and design of the various thermofluid systems. In addition to the technical skills development, this course aims to provide students with opportunities to continue with practice and development of professional skills such as team work, creativity, critical thinking, oral presentation, written communications and lifelong learning skills. Students gain a wide range of exposure to thermofluid engineering with appropriate applications of theory. This paper presents an overview of the course curriculum and innovative techniques used for both delivery and assessment for achieving excellence in "research informed" teaching and learning processes in thermofluid engineering. It is believed that, from this course of study, students could achieve effective learning techniques and gain advanced knowledge through research informed learning which they could practice in their professional career. The paper focuses on how the outcome of this study will impact on the progressive educational trend in the learning process and will give a better outcome for engineering as a profession.*

Introduction

Project based learning (PBL) is both a learning and teaching approach, an approach to curriculum that empowers learners to be self-directed, interdependent and independent learners (Krishnan 2011; Evensen and Hmelo, 2000). PBL has the potential to increase students' feeling of accountability for, and be in charge of his/her own learning. Students who are allowed to identify their own learning goals will be more engaged in learning. Facilitators can involve students in this process by helping them to create their project assignment or project checklist. This pre-project activity gives students significant experience in planning, and in setting their own goals and standards of excellence. Benefits that are attributed to project-based learning include increased motivation; increased problem-solving ability; improved library research skills; increased collaboration and increased resource-management skills. PBL allows the facilitator to incorporate various teaching and learning strategies that assist students in developing all of their knowledge acquisition capabilities. 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).

As indicated above, PBL is both a curriculum and a process. The curriculum consists of carefully selected and designed problems that demand from the learner the 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.

Traditional teaching techniques mainly concentrate on verbal or mathematical or logical intelligences only (Gardner, 1995). This can create annoyance for students who are not comfortable with traditional learning processes**.** PBL is a method of activity that highlights learning activities, and this approach is generally less structured than a traditional approach. The evidence from the literature suggests that the students are primarily intrinsically or extrinsically oriented toward learning. When students are motivated intrinsically, they tend to employ strategies that demand more effort and that enable them to process information more intensely (Lepper, 1988). Moreover, Condry and Chambers (1978) investigated that *when students were confronted with complex intellectual tasks; those with an intrinsic orientation used more logical information-gathering and decision-making strategies than did students who were extrinsically oriented.* Thomas (2000) pointed out the positive side effects of project based learning for students were the development of positive attitudes toward their learning process, work routines, abilities on problem-solving, and self-esteem. However, he also highlighted that the participants in PBL learn better and are more actively involved in their learning. On the other hand, the lecturers or tutors work as facilitators because students basically carry out their own projects.

PBL is a flexible approach to teaching that can readily be used in combination with other approaches. Instructors who make extensive use of PBL have found that they could merge a number of educational ideas with PBL, each supported by substantial research. *Howard Gardner's theory of* multiple intelligences, first put forth in 1983, supports the need for personalisation of schooling (Gardner, 1995). Gardner argues that *each person has a number of different types of intelligence. For example, people have musical intelligence, linguistic intelligence, and logical-mathematical intelligence. Through appropriate training and experience, these various intelligences can be enhanced - a person can develop his or her own individual potentials.* Gardner (1995) strongly supports the use of PBL as one approach to creating a learning environment that enhances each student's multiple intelligences.

The aim of engineering education is to develop skilled manpower to solve real life engineering problems and to meet society’s needs with advances in knowledge (Chowdhury *et al.*, 2010). Students could improve their learning methods and habits in higher education while learning to untangle real life problems through project based investigation. Gray (2006) investigated the integration of case study based investigations into engineering courses to establish a practice where undergraduate engineering students exercise their growing technical knowledge and analytical capability in the context of real engineering problem. Well implemented PBL is an effective tool for engineering education, with the students’ learning processes being improved by involving them more fully in the education process, and students’ participation can be facilitated by introducing the innovative technique in an attractive manner (Hassan *et al.,* 2011).

The addition of PBL into the “Thermofluid Engineering” course portrayed in this paper has provided the students to opportunity to enhance their basic knowledge of thermofluid engineering and to develop their professional abilities in real life. PBL is playing a key role in the enhancement of student participation in CQUniversity. PBL approaches are now becoming more a comprehensive platform in the engineering field of education at CQUniversity due to the students’ demand for greater use of the concept. This paper provides an analysis of the PBL approach along with the conventional approach in “Thermofluid Engineering” courses.

Summary of the course

CQUniversity offers a variety of engineering courses using a PBL approach in every term. Thermofluid Engineering is a 4th year undergraduate mechanical engineering PBL course, and has run very effectively for the last several years. On successful completion of this course, students should be able to demonstrate knowledge of the theoretical background of various thermofluid processes (such as air conditioning, refrigeration, fluid machineries, etc.) and their applications in industries. Students acquire high degrees of competency in team work, oral presentation, preparation of argumentative and persuasive styles of reports, and question and critique each others performance at a professional practice level. They also gain knowledge in self management and self directed learning for use after completion of this course. This project based course comprises both team and individual activities. Conventional lectures (2 hours), project workshops (2 hours), tutorial problem solving sessions (2 hours) and laboratory sessions (2 hours) in every week are the main components of this course.

Examples of Projects

Two projects are distributed to the students working in teams of 4 or less during the term. Each team needs to submit one report and give a presentation on the submission. Students are strongly advised to use peer assessment to ensure their progress is satisfactory. Examples of two projects are outlined below.

In project 1, students are required to study, analyse and assess the existing heating, ventilating and air conditioning (HVAC) system of an institutional building at the Rockhampton campus of CQUniversity in order to report whether the energy consumption can be reduced by introducing appropriate HVAC control strategies which could be incorporated with a building energy management system.

In project 2, students are asked to design and install a system to transport an industrial (alkaline) liquor from a large mixing tank to a precipitating tank and then to a resting tank at 30^{o}C.

Tutorial Problem Solving 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 and problem solving skills.

Laboratory

Students have to complete 4 laboratory sessions which are compulsory. Usually, they complete their laboratory works in a groups. Each team needs to submit a report within a fortnight following a laboratory session. It is expected that every member of a group contributes to the conduct, preparation and write-up of the laboratory report. On completion of the laboratory exercises, students are expected to gain experience on writing reports, perform relevant calculations and be able to understand the respective systems. It is expected that students will be able to apply those skills in completing their allocated projects in this course. Feedback is provided based on the ability to present reports on the laboratory work and how related questions and calculations as specified by the laboratory demonstrator/lecturer are addressed.

Workbook

In all technical areas it is customary to keep a workbook. The workbook should be a bound notebook in which the student details specific activities undertaken in each workshop, and records activities, changes made and results obtained. The entries should be updated for immediate reference so that activities need not be repeated and the student can refer back to what they have done. All tutorial exercises and other tasks based activities should be recorded in the workbook also.

Assessments

There is no conventional examination for this course. However, students are used to sit two class tests, one in week 6 (thermodynamics part) and another in week 12 (fluid mechanics part). Each test is of 90 minutes duration and closed book. If either test is failed, an opportunity is given to re-sit the test to achieve a satisfactory result. The tests are to determine the individual competency in technical skills and core concepts.

Besides this, all students are required to submit their final portfolio for the final assessment at the end of the semester. Student’s individual performance is assessed based on how well students have achieved the learning outcomes of the course according to the criteria listed in Table 1. Students can self assess their learning performance in a reflective manner against the learning outcomes, utilising all components detailed below as a minimum. Each student must nominate the grade that they think that should be awarded in accordance with the Assessment Criteria. The grade nominated by the student is to be justified in the written portfolio, and must be defended during an individual interview towards the end of the teaching period.

Table 1: Assessment Criteria

Grade if skills attempted diligently and assessed as competent	Grade if skills attempted diligently but assessed as not yet competent	Skill attributes attempted
High Distinction	Distinction	• Can use target content to reflect on own practice • Evaluate decisions made • Plan action to improve future practices • Generate new approaches • Demonstrate outstanding professional ability and attitude
Distinction	Credit	• Can apply course content • Recognise good and poor application of principles • Demonstrate excellent professional ability and attitude
Credit	Pass	• Understand declaratively (i.e., can summarise and report procedures) • Can discuss almost all content meaningfully • Know about the content but is not able to transfer or apply it easily • Demonstrate creditable professional ability and attitude
Pass	Pass conceded	• Understand declaratively (i.e., can summarise and report) • Can discuss over 75% of the content meaningfully • Know about the content but is not able to transfer or apply it • Demonstrate acceptable professional ability and attitude
Pass conceded	Fail	• Declarative understanding only • Evidence of considerable effort in the acquisition of terminology • Higher level understanding offset by some misunderstanding • Demonstrate marginally acceptable professional ability and attitude
Fail	Fail	• Fundamental misunderstanding of concept • Lack of effort and/or involvement • Cannot demonstrate acceptable professional ability and attitude

Portfolios

The portfolio is the full record of the student's journey throughout this course. It should include all notes, theory development, workbook and worked examples, class tests, laboratory sessions notes, projects, self assessment and explorations in design, management and team issues and weekly reflective journal entries.

Reflective journal and personal management

In the reflective journal section of the portfolio, students are required to reflect on how they have contributed to the learning outcomes in this course, what they have set out to learn and what they have achieved. The reflective journal should be submitted weekly with detailed evidence of their learning activities.

Quality Assurance

Teaching Evaluation and Performance

Several avenues of both formal and informal feedback confirm the success of our approaches to teaching used in this course. We solicit feedback from students directly by speaking to them, and usually get honest answers which enable us to make continuous improvement. We understand, however, that a detailed, honest comment may not always be given by a student in casual conversation. Rasul is proud of the following written comments made by a thermofluid engineering class – "*Overall, excellent teaching in this course. Plenty of opportunity to see Rasul if help is needed in the course content and he is open to help students to gain a good overall knowledge of the course material*" which demonstrates both approachability and interest in developing the best possible learning experience for students.

Incorporation of Student Feedback on Course Improvement

We used teaching and course feedback to improve the course development, delivery, learning and teaching. We followed the model of Morgan (2008) used at the University of Newcastle to incorporate the feedback from the students, target groups and peers. Morgan's model has also been practiced in other courses at CQUniversity (Chowdhury, 2010).

Innovative Learning and Teaching Practices

We have introduced a number of innovative learning and teaching practices and a modified assessment format into this PBL course on Thermofluid Engineering which we designed and developed, to allow students to build-up their research capability, thus enhancing their knowledge of and experience with the entire research process and lifelong learning. The design, development and delivery of this course for undergraduate students made an outstanding contribution to the learning and teaching efforts of the Faculty. We have actively pursued improvements in learning and teaching processes, practices and methodologies through:

- **Flexible Learning Workshops**

  In this course, lecturers conducted four sessions per week, lecture/workshop/tutorial/laboratories, with part of each lecture being devoted to practical workshop activities designed to reinforce the message of the lecture. This approach allows for significant flexibility, especially when the students are in work placement as a part of the co-op program, with the amount of time given to lecturing/practical experience varying each week depending on the demands of the topic. This approach has been successful in enhancing students' actual experience with research methodologies and active learning.

- **Innovative Assessment Practices**

  The assessment practices include giving students industry based open ended projects, which takes them right through the research process on a small scale. This allows students to experience many potential issues and pitfalls in engineering and science research, and to be better prepared for the workplace on graduation. Within the course we employ a flexible assessment system and reflective journals which allows students, within bounds, to design their own assessment profile. We also conduct a one to one informal interview, discussion and feedback session twice in a term with each student to ensure that students learn more out of the course. This allows students to best demonstrate what they have learnt. Bachelor of Mechanical Engineering students commented that "*We found the reflective journals outlined in the course to be more effective than the diary style reflective journals as used in other PBL courses. Compared to PBL subjects taken previously, the format of Thermofluid Engineering allowed us to develop and demonstrate our professional skills more effectively*".

Conclusion

PBL is a highly reputable part of the educational system and pedagogy of CQUniversity in engineering education. It is designed to teach the Thermofluid Engineering course so as to influence the students towards creative and critical thinking and lifelong learning, as these are the key elements for students in their real life problems. This paper describes an integrated assessment methodology including class tests, projects and portfolios which were implemented in this course, and the paper also demonstrates the effectiveness of PBL in facilitating engineering undergraduate students to gain essential skills for solving real life problems. Integration of conventional assessment methods with the PBL approach strengthens the learning requirements of students. Therefore, it benefits students to carry out reliable, multidisciplinary tasks in which they plan their time, make effective use of limited resources and work with other students. In addition to these benefits, the PBL approach encourages students to gain individual program learning outcomes. This subsequent learning outcome could be achieved through excellence in research and teaching. These outcomes are expressed in terms of knowledge and understanding, logical skills, practical and subject-specific skills and exchangeable skills.

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