Integration of project based investigation into an undergraduate fluid mechanics course for research and teaching excellence

Ashfaque Ahmed Chowdhury[1], M G Rasul[2] and M M K Khan[3]
College of Engineering and Built Environment, Faculty of Science, Engineering and Health
CQUniversity, Rockhampton, Qld 4701, Australia
Email: [1]a.chowdhury@cqu.edu.au; [2]m.rasul@cqu.edu.au; [3]m.khan@cqu.edu.au

Abstract: *The aim of the integration of project based investigation into an undergraduate fluid mechanics course is to involve students with real life engineering problems and to enhance the students' technical knowledge and problem solving skills. The classroom teachings, laboratory experiences and work on an engineering fluids project have been designed so that the students receive a broad range of introductory exposure to fluid mechanics with relevant applications of the theory. This paper highlights an overview of the course curriculum and assessment procedures for achieving excellence in teaching and research. It is anticipated that the students will be competent to make use of the advanced knowledge gained in this course in their professional career.*

Introduction

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. Holt (1996) reported that students often receive little practice in closing the gap between engineering necessity and technical knowledge. This lacking may lead to mistakes by the students in treating the engineering problems in practice. Jennings (1998) reported on a case where students were asked to expand on the professional dimensions of the implications of the problems they solved as a part of class room teaching and the outcomes of the solutions to engineering problems. Navaz et al. (2002) introduced a new approach in teaching Thermal/Fluid Sciences to undergraduate students through inclusion of new and advanced technologies into the curriculum using latest computational and experimental methods. Musto (2002) described the outcomes of the introduction of a project based approach in a numerical methods course where the subject concepts were related to a term-long design project. Student teams were required to report on the design methodology and the results through formal design reports and a presentation. The integrated project based approach assisted the students to enhance their enthusiasm and understanding of the course materials (Musto, 2002).

Mustoe and Croft (1999) reported the increased emphasis on open ended design exercises and case studies in engineering curricula. Gomes (2002) adopted case studies in modern engineering teachings to improve integration of cross disciplinary education and to develop a professional outlook in the young engineers. Feisel and Rosa (2005) identified the lack of coherent learning objectives in engineering laboratory exercises and demonstrated the impact of this shortcoming in limiting the effectiveness of these exercises. Feisel and Rosa (2005) encouraged engineering students to seek knowledge beyond the classroom theories. The integration of project based investigation into the fluid mechanics course described in this paper has not only provided the students an insight into the fundamentals of fluid mechanics, but also developed students' abilities to carry out professional tasks in real life.

Course overview

Initially the fluid mechanics course was offered to on-campus students. Later, the existing course was adapted for Interactive System-wide Learning (ISL) delivery on other regional campuses. An online lecture delivery was developed for flexible course offerings with a one week on-campus mandatory residential school requirement. The course presented the general characteristics of fluids, manometry, fluid statics, analysis of incompressible flow in pipes, analysis of buoyancy and stability of floating bodies and measurement of fluid flow. It introduced the methods of analysing fluid systems using the conservation of mass and momentum equations, Navier Stoke's equation combined with the concept of a control volume. To solve the problems in fluid mechanics course, students familiarised with the theories of incompressible flows in pipe systems, Euler's equation, Bernoulli's equation and the use of similitude and modelling principles and techniques. Students were required to act professionally in presenting information, communicating, working and learning individually and in peer learning teams to achieve the learning outcome of the fluid mechanics course.

Learning activities

At the beginning of the course, all students were given an overview of the course to make clear the expectations about how the course would operate. Flex students were introduced to online learning practice and were assessed on online learning skills required for this program. Students were encouraged to study and respond to the review questions and solve exercise problems. They were also familiarised with the real fluid systems and flow phenomena through the laboratory exercises. Students were required to study the text and other course materials as a guide to solve the workbook problems, virtual laboratory activities and other assessment items. Students were able to discuss their difficulties with problems in the discussion list or email the course lecturer. Students were expected to follow a self-directed study schedule which met the required deadline. The weekly schedule of activities for on campus students were Lectures (two hours per week), Tutorials (two hours per week), Laboratory (two hours per week). A residential school was conducted for flexible and other regional campus students after the midterm vacation. Tele-tutorials over Skype and/or local tutorials were arranged for off-campus students.

Mapping of graduate attributes

The targeted graduate attributes were Science and Engineering knowledge, Effective communications, Technical competency, Problem solving and systems approach, Functionality in a team, Social, cultural, global and environmental awareness, knowledge on sustainable design and development, professionalism and ethics and lifelong learning. The graduate attributes mapping was prepared to obtain an indication of how the fluid mechanics course contributed to achieve course learning outcomes and graduate attributes and to understand better how attributes are developed as students progress from one year to next year. This is done by indicating the graduate attributes targeted by each course learning outcome. The indicative marks are placed under the headings of Teaching, Practice and Assessment to illustrate the course emphasis (low/medium/high).

Course assessment items

To pass the course students had to attempt all the assignments, laboratory reports and complete all examinations and obtain a grade of at least 50% and a passing grade in the formal exam. Assessments for the course were on the basis of laboratory reports (20% weighting), a fluid mechanics project plan (20% weighting) and investigation (20% weighting), workbook submission (pass/fail in competency) and formal examination (40% weighting).

Laboratory exercises

There were three components in laboratory exercises – a formal lab report, video lab questions and virtual lab design and experimentation. The first two components were group assessment items and each group were required to submit a report on the assessments. Every group member contributed to the conduct, preparation and write up of the laboratory report. The objective of involving students in video lab questions and virtual lab activities is to develop higher order thinking from the problem statements and thus a deep understanding of the knowledge on the subject matters. Practical videos in most chapters of weekly schedules were uploaded on the course delivery site. The students were asked to solve the related practical questions demonstrating the steps with related background knowledge for a virtual lab problem. In the design and experimentation component, the students were encouraged to design an experiment in fluid mechanics from any of the topics covered in the weekly modules that the students would like to improve further in future. Students were required to submit a report on the selected experimentation covering the necessity for the investigation, a description of the work, the parameters requiring observation and the safety procedures. Students were also required to complete the entire laboratory exercise including the drawing of graphs and final answers on issues such as calibration of obstruction meter, flow in pipes, stability of a floating body and velocity profile and pressure losses in a smooth pipe.

Engineering fluids project

The aim of an engineering fluids project is to ensure that the future engineers will comply with the principles of sustainability though improving their research ability and knowledge of fluid mechanics. The projects related to basic principles of fluid mechanics assist the students to enhance their learning experiences and to achieve the graduate attributes through a team based design approach utilising the concept of sustainability to meet the needs of present and future generations. The students experienced a productive pedagogy in fluid mechanics through improved knowledge & understanding.

Several project options were available for the students. In a project proposal, on part of land assumed, the right side was assumed to construct an engineering complex. Based on the knowledge in the course, a group of students were responsible to design the supply of drinking water and the management of waste water facilities for the engineering workshop. Another two groups of students were assigned to design the same for a shopping complex and a cinema theatre. There were several steps suggested in the course profile for the students to follow and report to the campus tutors on the progress of the project. In the first two to four weeks, students were required to define problems and project scope through the fundamentals of fluid mechanics learnt, and then proposes a sustainable concept design complying with course learning outcomes. In week five, students were required to present the progress in groups identifying the contribution of each member. In the next three to four weeks, students prepared the preliminary sustainable design with specifications. Often students revisited the preliminary plan and refined the concept design with the feedback from course tutors and lecturer. Later in the term, students finalised and documented the sustainable design with a strategy to implement in future. It was required to build a physical prototype design to have a nice memory of the young engineers efforts in future.

The amount of traditional homework problems assigned was reduced approximately by half. The design project was assigned to groups of four or five students at the start of the course. Handing out the project immediately at the outset of the course, where students are largely unfamiliar with the material required for the completion of the project, renders the learning process goal driven. This approach is in support of the life-long learning scenario for which students ought to be prepared and where the learning typically occurs on a needs basis in an interactive and often collaborative learning mode. The submissions of two written progress reports were required in order to guide students through the design tasks and enforce progress throughout the entire semester. In addition, a total of two class periods throughout the semester were allotted for a progress presentation and a final presentation by each student team. It was found that the project based learning concepts enhanced students' learning experiences and assisted in the achievement of key attributes. The students experienced a dynamic pedagogy in fluid mechanics through improved content quality, connectedness to real world problems, a supportive team learning environment and recognition of differences between the team members. A pictorial view of the student's project work on the design of the water supply system for a shopping complex is shown in Figure 1.

Other assessment items

To improve the research capability and gain knowledge and improve understanding in fluid mechanics, students were asked to prepare a teaching and learning journal in fluid mechanics through the lectures, tutorials, experiments and project work. Students were expected to solve higher order problems and open answers which require researching on the weekly topics. The workbook contributed to the overall grade of the course as it supplemented the assignment work and confirmed students overall competency. They were required to show the application and understanding of the subject matter and to use the correct procedures and calculations in their workbook answers. Attainments of competency attracted extra marks to move to a higher grade when short by a few marks. Students were also required to sit for closed book final exam.

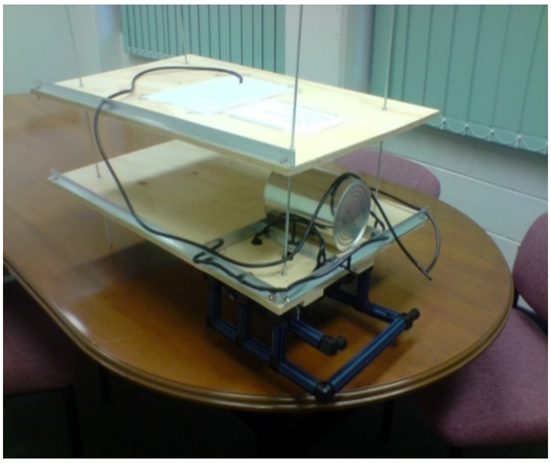

Figure 1: A prototype design of a student group project

Evaluation criteria

The laboratory components of the assessment items were assessed based on reporting of key elements required to undertake the laboratory sessions, clarity of expressions, appropriate referencing of sources, accurate use of fluid mechanics knowledge, presentation of mathematical formulation, clarity and logical presentation of ideas and arguments by means of data analysis and synthesis. Engineering fluid projects and workbooks were evaluated based on the evidence of the application and integration of knowledge and understanding of the material studied and communication and justification of the subject matters. It was kept in consideration that students demonstrated accurate use of engineering terms, collection and organisation of information in the various forms of presentation. It includes well structured solutions, use of engineering mathematical reasoning and proof to develop logical arguments, recognition of the effects of assumptions used, evaluation of the validity of arguments and justification of procedures.

Students performance

Course history showed that, after introduction of the integration of project based investigation in fluid mechanics course, on average (based on three years data), about 4.6% of the total enrolled students withdrew from the course after enrolment and the failing rate dropped to 6.5%. Most of the students performed very well and their overall performance was quite impressive. On an average, 28.7% students received high distinction and 30.6% students received distinction in the course. As shown in Figure 2, the comparisons of student performances over 2007 and 2008 demonstrate that the failing rate of the students in the course was reduced from 14.3 percent to 5.4 percent. The blended assessment mechanism incorporating lab components, project works, workbook and final exam assisted students to understand the subject matter and to develop a higher level of skills in an advanced engineering topic like fluid mechanics.

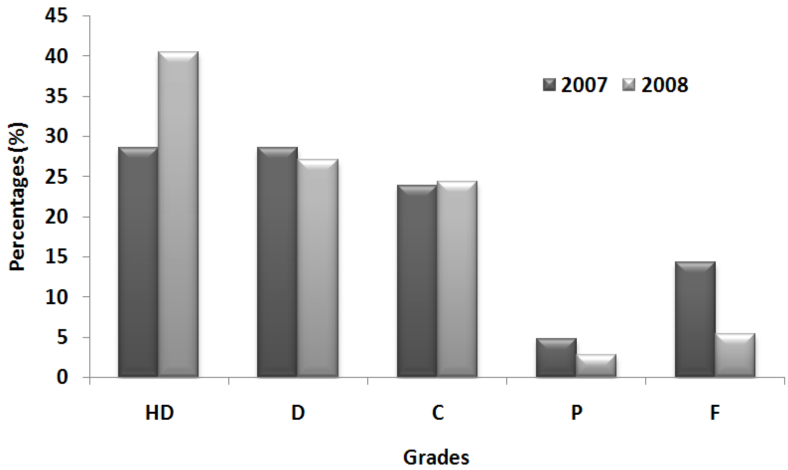

Figure 2: Indication of students' performance in the course

Further development

The program review committee meeting at CQUniversity suggested the Program Director the course outcome, students' feedback, and peer assessments (tutors and course coordinator) – Engineering and Physics for potential improvement of the next offering of the course. In 2009, based on student comments and peer assessment, the course was progressively restructured to maintain the relevance of the content and satisfy the demand and need of the industry and community. Dr Philip Morgan's (the University of Newcastle) flowchart (Figure 3) was followed to incorporate the feedback from the past students, tutors, lecturer and course coordinator. To collect the feedback received from the student, course evaluation and focus group interviews were conducted. Some feedbacks were received from open ended comments by the students in the emails. The summary of the results of the feedback and recommendations have been articulated in the course improvement flowchart.

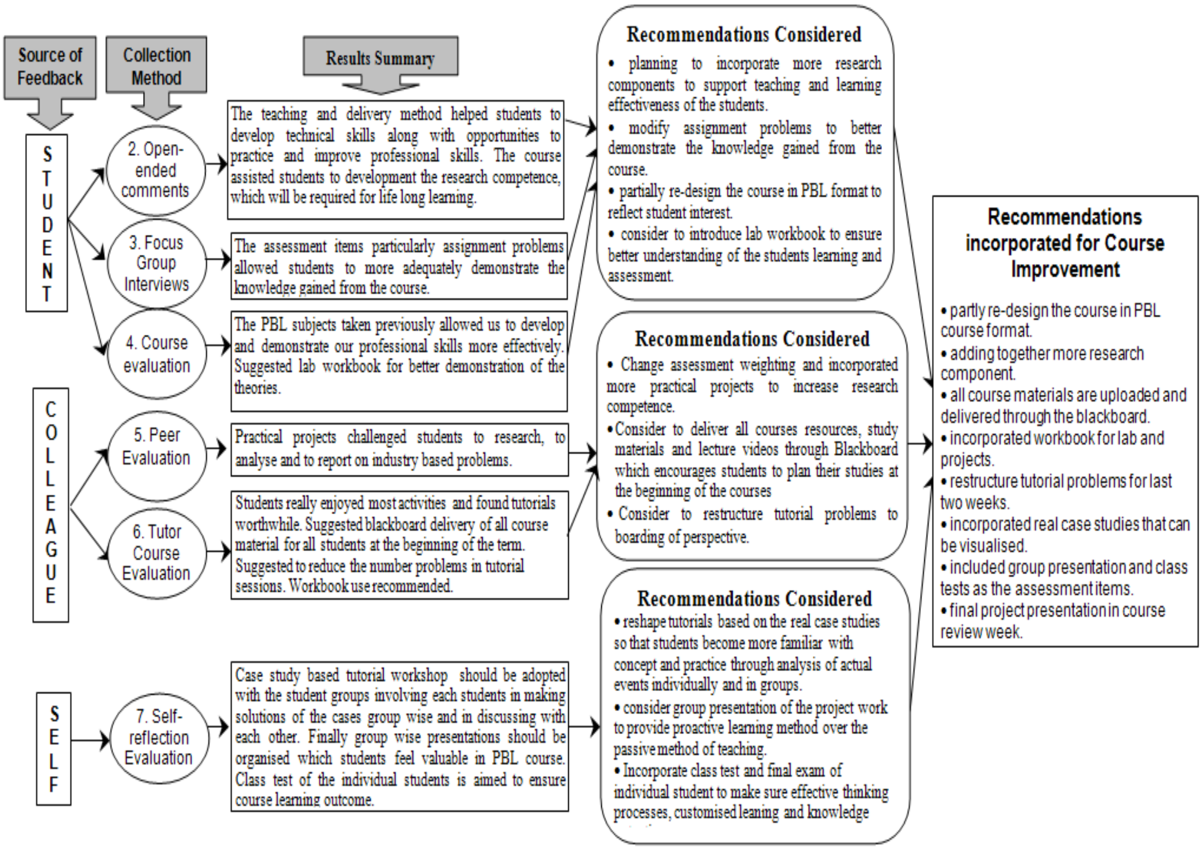

Figure 3: Flowchart of course improvement process

Concluding remarks

The paper describes an integrated assessment methodology which was implemented in a fluid mechanics course and demonstrates its effectiveness in facilitating engineering undergraduate students to become efficient problem solvers of real life problems. The success of the assessment procedures were evaluated based on the successful completion of the course, students' grades, students' withdrawal rate from the course and the students' overall perception of benefits of the course studied. Integrated assessment methods assisted with strengthening previous and prerequisite learning requirements. Therefore, benefits the subsequent learning process is achieve through excellence in research and teaching. The assessment items offered students experience of real life problems in a professional manner. Further improvement of the course is in progress considering the feedback from all the stakeholders of the course.

Acknowledgement

The authors gratefully acknowledge the contributions of Ahmed Elgezawy and Fons Nouwens who generously assisted in the development and implementation of the course in the faculty. The authors also acknowledge the support of the Learning and Teaching Education Research Centre (Special Interest Group – Future Engineering Education Directions), which is established and supported under CQUniversity's Research Centres Program.

References

Dye, R. C. (2003). A computer-generated 'pseudo-experiment' in fluid mechanics. *International Journal of Mechanical Engineering Education, 31* (2), 143-149.

Feisel, L. D. & Rosa, A. J. (2005). The role of the laboratory in undergradaute engineering education. *Journal of Engineering Education* (January), 121-130.

Gomes, V. (2002). Consolidation of engineering education through industrial case dtudies. *International Journal of Engineering Education, 18* (4), 479 - 484.

Holt, J. E. (1996). On the nature of mechanical engineering - an rngineering ethos. *International Journal of Engineering Education, 12* (5), 332-338.

Jennings, A. (1998). Viewpoint: the need to upgrade experimental learning. *International Journal of Engineering Education, 14* (2), 83-88.

Musto, J. C. (2002). A project based approach to teaching numerical methods. *International Journal of Mechanical Engineering Education, 30* (3), 233-247.

Mustoe, L. R., & Croft, A. C. (1999). Motivating engineering students by using modern case studies. *International Journal of Engineering Education, 15* (6), 469 - 476.

Navaz, H. K.., Henderson, B. S., Berg, R. M. & Nekcoei, S. M. (2002). A new approach to teaching undergradaute thermal/fluid sciences - courses in applied computational fluid dynamics and compressible flow. *International Journal of Mechanical Engineering Education, 30* (1), 35-49.