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Improving Learning Experience by Embedded Project-based Learning and Mixed-mode assessment in Computational Statics and Dynamics Course

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ABSTRACT

CONTEXT

6522ENG Computational Statics and Dynamics is a third-year course in the Bachelor of Engineering (Honours) program and a core course for the Master of Professional Engineering program in the School of Engineering and Built Environment, Griffith University. There are approximately 60 students enrolled annually. 6522ENG is 12-week, 10 credit-point course that corresponds to one-quarter of the typical full-time load for the trimester. This course presents continuum mechanical basics and computational algorithms to analyse engineering components and structures under arbitrary loading conditions. The course is organised by project-based learning approach (PBL). Students also gain skills in using a finite element analysis package and further deepen their knowledge via two group-projects and two individual exams.

PURPOSE

The purpose of implementing PBL in 6522ENG at Griffith is to enhance the students' learning experience. The motivation for implementing PBL and two individual exams is to introduce concepts early in a course, tie concepts together while monitoring the students' learning process. It encourages students with an active learning experience that aims to simulate a "real-world" engineering experience.

METHODOLOGY

We constructively align the course with Griffith Graduate Attribute and Engineering Australia Stage 1 Competencies via a weekly 2-hour lecture, a 1-hour tutorial and a 2-hour scheduled laboratory time for project work. The assessment plan is designed as a mixed mode with four steps. Group work is project-based learning, known as a pedagogy approach for engineering education (Helle et al., 2006). The large project is divided into two phases, assessed at the fourth and eleventh weeks. Tests are individual work introduced before the first project assessment and after the second project assessment. These tests aim to monitor and promote student engagement. This mixed-mode assessment has been proven efficient in engineering education, and project-based learning has been demonstrated as a key component of engineering programs (Mills and Treagust, 2003).

We use four indicators to evaluate the effectiveness of this approach: feedback from students via student surveys, grade distributions, responses on the test, and the practical success of the proposed project. The survey results were the general university' student experience of courses' that students voluntarily complete. The survey consists of two open-ended questions and six statements ('questions') that quantify students' respond. The survey also includes the students' feedback on online experience during the pandemic Covid-19.

RESULT

Overall, we were able to describe a successful implementation of a project-based learning component in an undergraduate course on computational statics and dynamics. The main merit of the embedded project was in providing hands-on experience of finite element method in design a real engineering structure. This served as scaffolding for introduction of new concepts within the course material. The extensometers, designed by students' project, were well-covered by design, analysis, simulation, and validation steps. Students demonstrated geometry optimisation utilising finite element method by both commercial software and hand-calculation, validated result with analytical solution. Students were able to discuss calibration protocol and the selection of electronics components necessary in real engineering design. Furthermore, students enjoyed the course, engaged well with the project and performed well on all assessment items and exam questions connected to the project's themes.

KEYWORDS

Project-based Learning, Computational Statics and Dynamics, Finite Element Method,

Introduction

Griffith University has emphasised its vision to enhance student learning outcomes, engagement and improve retention by implementing a student-focused learning approach. At Griffith University, Mechanical Engineering discipline has been implementing a range of project-based learning (PBL) initiatives to wholly continuous assessment courses with a strong PBL focus (Palmer and Hall 2011; Hall et al. 2012). This paper presents a third-year mechanical engineering computational statics and dynamics course which was developed using a design-and-build project as the central theme and integrating individual assessment as monitoring tools since 2020.

The PBL approach itself has received much interest, particularly for engineering education (Frank et al. 2003; Helfenbein et al. 2012; Krishnan & Nalim 2009; Lima et al. 2007, Mills & Treagust 2003) since it can shift the learning process closer to a ‘real-world’ engineering experience and improve connections to the desired graduate attributes. Students do their own learning and the lecturer takes on coaching or supporting role to teach students’ how to learn’ rather than being a ‘provider of facts’ to passive listeners (Frank et al. 2003). Helle et al. (2006) suggests three different purposes for implementing PBL, including the promotion of “concrete and holistic experience regarding a certain process”, “integration of subject material”, and “self-regulated deep-level learning”. These promotions are the motivation for implementing PBL in 6522ENG Computational Statics and Dynamics at Griffith University. The implementation will reduce ‘chalk and talk’ pedagogy and was motivated by a desire to enhance further the learning experience rather than completely replace the existing pedagogy. The purpose of implementing PBL in 6522ENG at Griffith is to enhance the students’ learning experience. The motivation for implementing PBL and two individual exams is to introduce concepts early in a course, tie concepts together while monitoring the students’ learning process. It encourages students with an active learning experience that aims to simulate a “real-world” engineering experience.

Context

The Course

6522ENG Computational Statics and Dynamics is a third-year course in the Bachelor of Engineering (Honours) program and a core course for the Master of Professional Engineering program in the School of Engineering and Built Environment, Griffith University. There are approximately 60 students enrolled annually. 6522ENG is 12-week, 10 credit-point course that corresponds to one-quarter of the typical full-time load for the trimester. This course presents continuum mechanical basics and computational algorithms to analyse engineering components and structures under arbitrary loading conditions. The course is organised by PBL approach. Students also gain skills in using a finite element analysis package and deepen their knowledge via two group-projects and two individual exams.

Assessments for the course were as listed in Table 1. The project reports (15% and 25%) are directly connected to the project. Students worked in groups, but all students were required to submit individual project reports.

Table 1: Course Assessments

Assessment Item	Weighting
Problem-solving test (individual work)	15 %
Initial project report (group work)	15 %
Final project report (group work)	25 %
Final Exam	45 %

The Project

The task for student is to work in groups of four to design a clip-on extensometer. Extensometer is a convenient tool mounted directly onto the specimen to accurately measure the average strain in the gage section of a material test specimen. The knife edges transfer extension from the specimen to the internal transducer are short and stiff, so there is practically no relative movement between the specimen and the extensometer, resulting in a high level of measurement accuracy. The elongation results in a ‘bending strain’ can be recorded by a strain gauge.

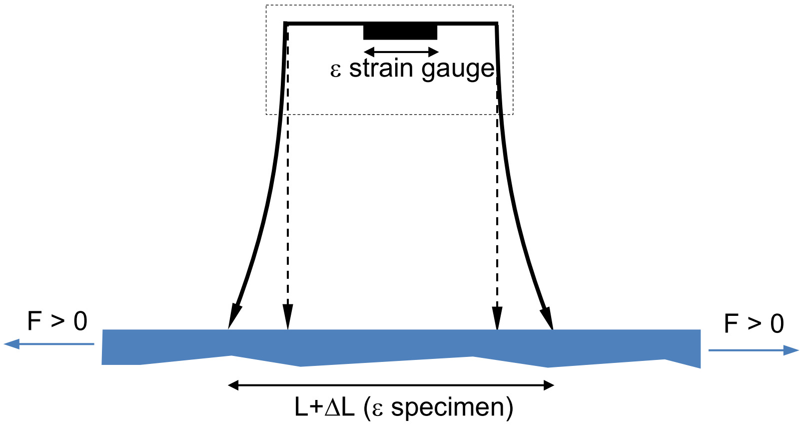


Figure 1: Extensometer design requirements

Student needs to design the extensometer based on both differential equation-based approach and the finite element method, and compare those results. The goal is to derive the relation between the specimen’s deformation/strain with those in the sensor. For the finite element approach, student will justify the selection of element type, mesh density and explain the chosen dimensions of the sensor. As an engineering project, a geometry optimisation process is required. The results also include a completed manufacturing drawings, assembly instructions, selection of sensor, manufacturing method, discussion on calibration protocol and estimated cost of the designed extensometer.

Pedagogy

We used various aspects of the project throughout the course. In particular, the concepts of material strength, partial differential equations, truss, beam, plane elements, were illustrated in connection with the project. The more fundamental topics provided the scaffolding required for understanding extensometer design via a weekly 2-hour lecture, a 1-hour tutorial and a 2-hour scheduled laboratory time for project work. The assessment plan is designed as a mixed-mode with four steps. The large project is divided into two phases, assessed at the fourth and eleventh weeks. Tests are individual work introduced before the first project assessment and after the second project assessment. These tests aim to monitor and promote student engagement. This mixed-mode assessment has been proven efficient in engineering education, and project-based learning has been demonstrated as a key component of engineering programs (Mills and Treagust, 2003). Additionally, each project is given a specified set of product requirements which will result in unique design and output of the project.

Methodology for analysis of initiative

We use four indicators to evaluate the effectiveness of this approach: feedback from students via student surveys, grade distributions, responses on the test, and the practical success of the proposed project. The survey results were the general university’ student experience of courses’ that students voluntarily complete. The survey consists of two open-ended questions and six statements (‘questions’) that quantify students’ respond. The survey also includes the students’ feedback on online experience during the pandemic Covid-19. Students can respond on a five-point scale ranging from strongly disagree (SD), disagree (D), neutral (N), agree (A) to strongly agree (SA). SD has a point value of 1 and SA a point value of 5. The questions are given in Table 2. Survey responses are done online before students take the final exam.

Table 2: University-wide Survey Questions (SEC)

Question (Statement)	Responses
Q1 This course was well-organised.	SD,D,N,A,SA
Q2 The assessment was clear and fair.	SD,D,N,A,SA
Q3 I received helpful feedback on my assessment work	SD,D,N,A,SA
Q4 This course engaged me in learning.	SD,D,N,A,SA
Q5 The teaching (lecturers, tutors, online etc) on this course was effective in helping me to learn	SD,D,N,A,SA
Q6 Overall I am satisfied with the quality of this course.	SD,D,N,A,SA
Q7 What did you find particularly good about this course?	Open
Q8 How could this course be improved?	Open

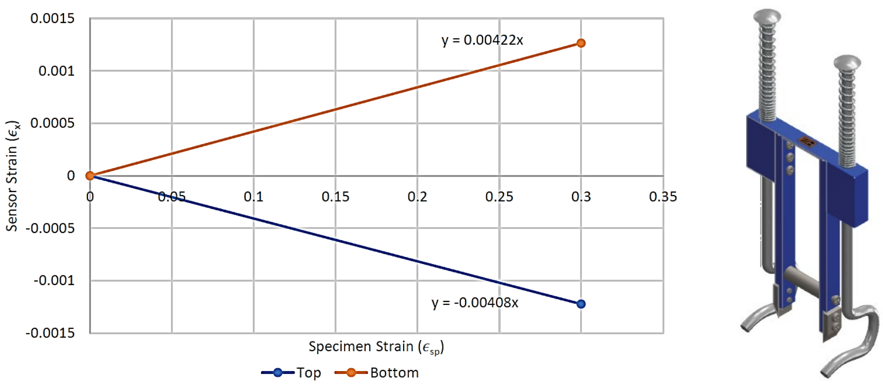
Approval was obtained from the ethics and integrity team at Griffith University to make use of the student data in this research.

Results and Discussion

Connecting theory and experiment – *a concrete and holistic experience*

All 22 student groups succeeded in designing, simulating, and validating extensometer, which yielded meaningful results of the engineering design process. Figure 2 shows a result from a student project. The graph is a typical calibration curve after performing the extensometer's dimension optimisation to reach the highest performance with minimal material cost. The mathematical background of the project is to solve partial differential equations with an analytical approach, and by finite element simulation (FEM approach) where students build their own stiffness matrix. These results are then compared with those of commercial package (ANSYS APDL). A script of simulating code and engineering design (e.g. detail drawing of Fig.2b) were submitted together with the report.

Overall, the practical implementation of the project can be judged a success. The student-designed extensometer all showed the deformation from the specimen is scaled down to those at the straingauge, which is well described in the report and reflected via 3D engineering design.



(a) (b)

Figure 2: Typical results for extensometer design with (a) relation between speciment's strain and sensor' strain, and (b) a 3D CAD design.

Student perceptions of the course

The course was very well received by students. Figure 3 gives the distribution of responses to the first six questions listed in Table 2. 25 (39 %) of the 63 students enrolled in the course responded to the survey. On average, the students agreed or strongly agreed that the course was well organised, the assessment was fair, the feedback was helpful, the course was engaging and the teaching was effective. Although the question "engaged learning" had some negative responses at D or SD, 88 % of the response was positive (A or SA). In relation to the PBL component, it is difficult to differentiate between its effect and the other pedagogical methods employed in the course. However, the responses for Q4 (This course engaged me in learning) and Q5 (The teaching on this course was effective in helping me to learn) are encouraging since the main role for PBL in this course is to engage the students in learning.

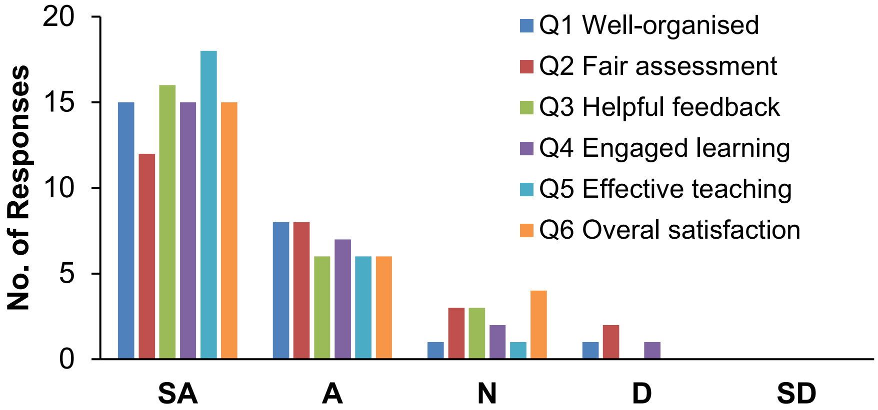


Figure 3: Distributions of responses to the six questions on the student survey

The responses to qualitative questions did not clearly indicate if the students particularly valued or even recognised the role of the project in the course. Figure 4 summarises the responses to the open questions (Q7 and Q8 in Table 2). In relation to 'what the students found particularly good about the course', students mentioned the "two stage assessment structure" and "industrial related content". However, the most common response is "well structure" of the course. Given that the project played an essential role in the content delivery, it seems reasonable that the embedded project with two-stage assessment contributed towards the positive feedback about course content and assessments.

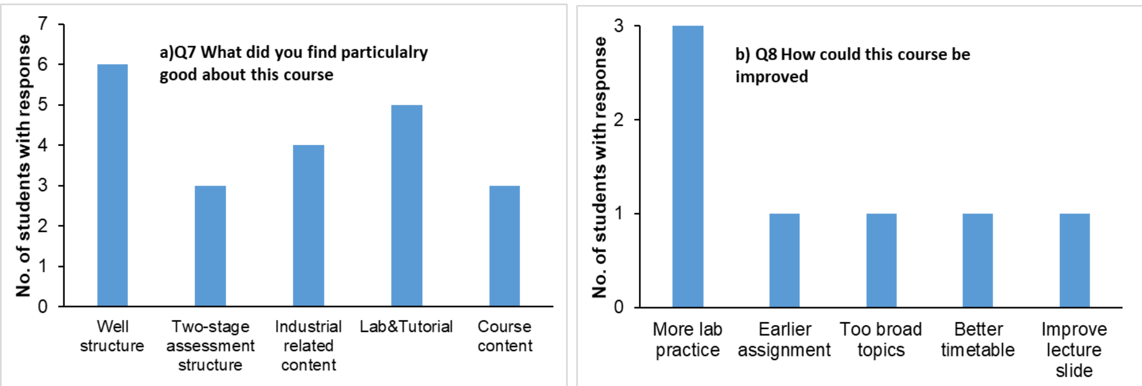


Figure 4: Summary of student responses to the qualitative questions

Figure 4(b) presents the feedback that the students would like to have more lab practices and an earlier assessment. There was a lack of qualitative feedback directly connected to the project embedded in the course.

Learning outcomes

Figure 5 shows the grade distributions for the assessment items and the overall grade for the course. Students invested considerable effort into their project reports and did a commendable job. The overall grade distribution is also good, with a peak at the credit level. While the course was a success based on measured learning outcomes. It is difficult to say how much of the success can be attributed to the project-based learning component.

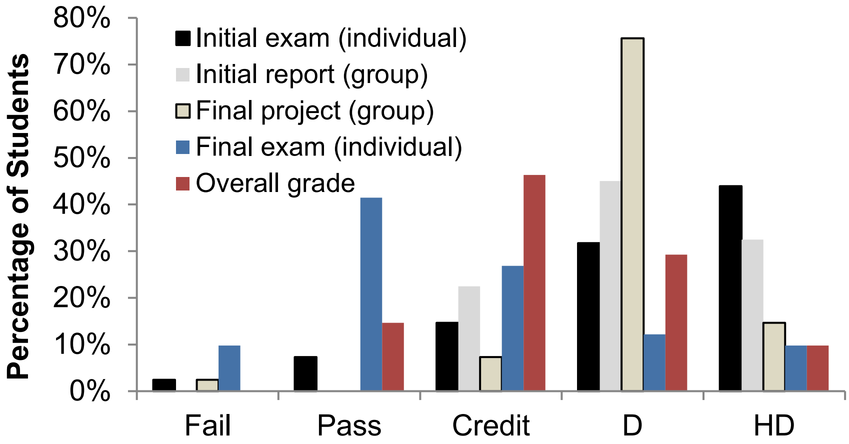


Figure 5: Grade distributions for the project report, the final exam and overall for the course

Conclusion

We were able to describe a successful implementation of a project-based learning component in an undergraduate course on computational statics and dynamics. The main merit of the embedded project was in providing hands-on experience of finite element method in design a real engineering structure. This served as scaffolding for introduction of new concepts within the course material. The extensometers, designed by students' project, were well-covered by design, analysis, simulation, and validation steps. Students demonstrated geometry optimisation using the finite element method by both commercial software and hand-calculation, validated results with analytical solutions. Students were able to discuss calibration protocol and the selection of electronics components necessary in real engineering design. Furthermore, students enjoyed the course, engaged well with the project and performed well on all assessment items and exam questions connected to the project's themes.

References

Bergman, T. L., Lavine, A. S., Incropera, F. P., & DeWitt, D. P. (2011). 'Fundamentals of Heat and Mass Transfer', 7th Edition, Wiley.

Frank, M., Lavy, I., & Elata, D. (2003). Implementing the project-based learning approach in an academic engineering course. *International Journal of Technology and Design Education*, *13*, 273-288.

Helfenbein, R. J., Nalim, R., & Rajagopal, M. (2012). *Work in progress: faculty perceptions of project-enhanced learning in early engineering education: barriers and benefits*. Paper presented at the Frontiers in Engineering Education Conference (FIE), Seattle, WA.

Helle, L., Tynjala, P., & Olkinuora, E. (2006). Project-based learning in post-secondary education – theory, practice and rubber sling shots. *Higher Education*, *51*, 287-314.

Krishnan, S., & Nalim, R. (2009). *Project-based Learning in Introductory Thermodynamics*. (AC 2009-1911) Paper presented at the 116th American Society of Engineering Education Annual Conference, Austin, TX.

Lima, R. M., Carvalho, D., Flores, M. A., & Van Hattum-Janssen, N. (2007). A case study on project led education in engineering: students' and teachers' perceptions, *European Journal of Engineering Education*, *32*(3), 337-347.

Mills, J. E., & Treagust, D. F. (2003). Engineering education – is problem-based or project-based learning the answer? *Australasian Journal of Engineering Education*, *3*(2) 2-16.

Palmer, S., & Hall, W. (2011). An evaluation of a project-based learning initiative in engineering education. *Journal of Engineering Education*, *36*(4), 357-365

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