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Evaluation of Assessment Methods in Problem and Project-Based Learning

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ABSTRACT

CONTEXT

1801ENG,Introduction to Structures is a core course for first-year students in Bachelor of Architecture at Griffith University. A Problem and Project-based Learning (PPBL) approach with assortment of individual and teamwork activities and assessment items were used to deliver the course. The assessment methods and their alignment with learning outcomes were evaluated based on historical evidence of student performances and Student Experience of Course and Teaching surveys from 2016 to 2020. The evaluation helps in redesign of the assessment and learning activities for future offerings of the course with enhanced student learning outcomes.

PURPOSE OR GOAL

Non-Engineering students (such as Architects) normally do not perform well in courses that have engineering mechanics components. Instead of conventional theoretically demanding methods of teaching, a PPBL approach has been used to teach these courses. This study aims to understand and discuss the students' perception of the PPBL approach, and the assessment items involved in this approach.

APPROACH OR METHODOLOGY/METHODS

The students' performance and their evaluation of course and teaching surveys were analysed over five course offerings (in five consecutive years). A five-point Likert scale survey was conducted in 2020 from previous students enrolled in the course from 2016 to 2019. The survey aimed to find links between students' perception of the PPBL approach with the corresponding assessment items. Moreover, appropriateness of the assessment items and their alignment with the course and program level learning outcomes were also analysed using the survey.

ACTUAL OR ANTICIPATED OUTCOMES

Majority of students found PPBL engaging and motivating. The final design project and analytical report were ranked more favourite assessment items compared to written quizzes and laboratory tests. Students reported that the two former assessments are better aligned with the adopted PPBL approach. The current results agree with findings in literature that enforcing students to maintain a reflective journal (known as logbook herein) has positive impact on their retention of knowledge.

CONCLUSIONS/RECOMMENDATIONS/SUMMARY

Adopting PPBL teaching approach shows positive impact on students' engagement and ability to integrate theory and practice. It is understood that, to achieve the intended PPBL outcomes, the assessment items should be designed to encourage critical thinking and problem-solving capacities in students. Furthermore, analysis of current results suggest that a combination of assessment items shall be provided to improve the learner's capacity to work independently as well as to give them a sense of connection.

KEYWORDS

Problem and Project-based learning; Assessments for learning

Introduction

The structure of a building significantly affects the architectural design and its construction. Hence, teaching structures is an essential part of Bachelor of Architecture worldwide (Estes & Baltimore, 2014), as well as at Griffith University through a common first-year course "1801ENG, *Introduction to Structures*" offered to multi-disciplinary group of students from architectural design, industrial design, construction management and engineering. Understanding a structure requires a sound knowledge of mathematics and fundamentals of engineering mechanics and strength of materials. Unlike engineering students, most architectural students either: (1) lack the basic knowledge of mathematics and physics (Salvadori, 1958), or (2) do not find the conventional engineering teaching methods engaging (Chiuini, 2006). Previous educators have used array of methods to overcome these obstacles in teaching structures to non-engineers. Most important are the works of: (Vrontissi, 2015) using analogy methods to relate examples from nature in teaching, (Ogielski, Pelczarski, & Tarczewski, 2015) by means of physical modelling to help learners shape the structural intuition, (Pedron, 2006) using interactive online Tools (*eQUILIBRIUM and Zometool*) to graphically illustrate statics concepts, as well as exploiting hands-on (Emami & Buelow, 2016) and multimedia tools (Vassigh, 2005). One of the most effective methods are known to be the project-based learning (PBL) and problem and project-based learning (PPBL), as outlined by (Atadero, Balgopal, Rambo-Hernandez, & Casper, 2014) teaching statics, (Muhsan & Albarody, 2019) teaching mechanics, (Dym, Agogino, Eris, Frey, & Leifer, 2005) teaching engineering design. Moreover, previous studies have proven the significant effect of assessments used in PBL methods on stakeholders satisfaction (Van den Bergh et al., 2006), creative thinking (Doppelt, 2005) improving generic professional skills (Hosseinzadeh & Hesamzadeh, 2012) and enhancing cognitive measures, reasoning and self-directed learning (Hmelo, Gotterer, & Bransford, 1997).

Hence, 1801ENG, *Introduction to Structures* was re-structured in 2016 and PPBL method was used to teach the course (Karampour, Gilbert, Guan, Gunalan, & Howell, 2016) to meet the needs of students from various backgrounds and different programs. An assortment of assessment items was incorporated to fulfil the learning outcomes of the PPBL approach. The main aims of introducing PPBL and design of assessment items in the re-structure were to: (1) make the Learning and Teaching (L&T) activities engaging by motivating students, giving them a sense of purpose and encouraging teamwork culture, and (2) improve knowledge retention by integrating theory and practice, enhancing critical thinking and problem-solving skills and improving their independent professional judgement. Moreover, change from a Quiz in week 4 to a problem-solving assignment aligned with the final project on student performance and participation rate is discussed.

This paper reviews the efficiency of the adopted strategies by analysing the students' performances in the L&T activities and assessments and their feedbacks.

Learning and teaching activities and assessment items

The course introduces structural concepts to architecture students and enables them to apply the knowledge gained during the course to conduct preliminary design of their ideas which are structurally feasible, sustainable and structurally sound. A combination of weekly lectures and tutorial/workshops was implemented in teaching the course from 2016 to 2019 and since 2020, the course is offered in blended mode (online and face-to-face). In a 12-week trimester, the first four weeks are allocated to fundamentals of engineering mechanics and reinforcing the mathematics/physics background knowledge. During this period *problem-based learning* method is used and a series of hands-on activities is developed to help the students understand the fundamentals of static equilibrium through experiential learning (Gunalan, Gilbert, Guan, Karampour, & Crough, 2018). Snapshots of sample activities used to teach how to calculate reaction forces or deflections in beams are shown in Figures 1 and 2, respectively. Students are assigned in groups of 3 to 5 to conduct each activity according to stepwise instructions provided for each activity.

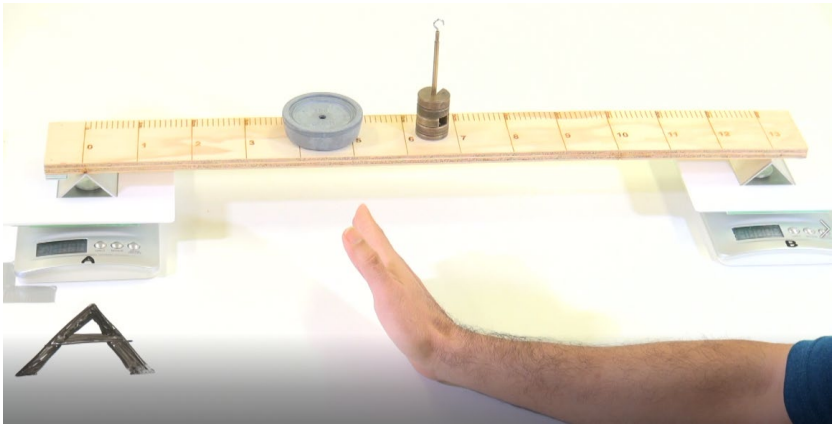

Figure 1: Snapshot of a sample hands-on activity to find beam support reactions.

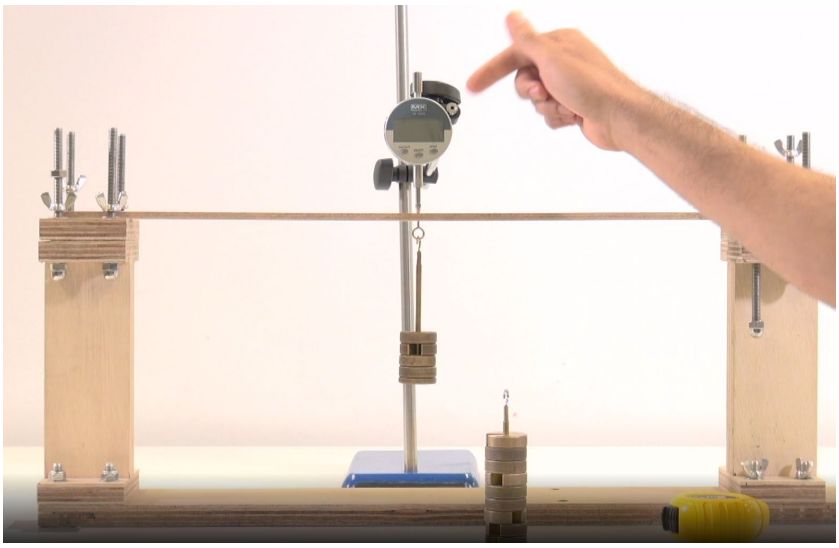

Figure 2: Snapshot of a sample hands-on activity to find beam deflections.

The L&T activities in the mid-trimester (weeks 5-9) are allocated to structural systems and their analyses, and final three weeks are dedicated to the final project, which is the preliminary design of a two-story house. During the final 3 weeks a *project-based learning approach* is adopted in which the theory is taught during the design process and feedback is provided in the tutorial sessions. The students are asked to reflect on their work by keeping a logbook of activities that is also a portfolio of their progress and achievements towards the final project. The learning outcomes of the course are: (1) State and describe structural engineering principles and terminologies at a basic level, (2) Calculate, interpret and solve introductory structural engineering problems, (3) Recognise, define and explain principles, behaviour and limitations associated with a range of structural materials and systems and how they might work together, (4) Identify the structural/stability components in existing structures and describe their role in the structural system, (5) Select, justify and evaluate appropriate structural systems in a preliminary design, and (6) Practice group work and evaluate work of others.

The assessment items and co-relation with learning outcome (LOs) are:

1. Problem-solving assignment (2020-) with a 10% weighting, replacing the previous Mechanics Quiz (2016-2019), is due end of week 4. Students' understanding of equilibrium and statics is assessed (LO 1,2);

2. Online Written Quiz (2020-) with a 20% weighting, replacing the previous in-person one (2016-2019), is due end of week 6 to assess students learning of beam theory from the hands-on activities (LO 2,3);
3. Analytical report with a 20% weighting due end of week 9, helps students to develop a sense of structural design by observing and analysing the role of individual elements in real-life structural systems (LO 3,4);
4. Final design project, due end of trimester, is a group work and weighs 45%. A conclusive report of the architectural design and drawings and structural design and supportive calculations are assessed (LO 1,2,3,4,5,6);
5. Individual reflective journal (logbook), which weighs 5%, is checked twice in the trimester to provide constructive feedback on students' reflection (LO 1,2,3,4,5,6);.

Analysis

In 2020, 60 participants from (2016-2019) cohorts were asked to participate in an anonymous online survey of 1801ENG, *Introduction to Structures*. Out of the participants, 8.5%, 28.8%, 27.1% and 35.6% were from cohorts of 2016, 2017, 2018 and 2019, respectively. Using a 5-point Likert scale questionnaire, responders were asked to specify their level of agreement to statements about learning and assessment activities. Moreover, students were asked to write any plus, minus or interesting aspects of the course. A total of 37 participants (61.7%) provided written comments. The results are represented in Table 1 and are discussed in the next section to evaluate the PPBL method and assessment items.

Table 1: Results of the anonymous online survey of students from different cohorts 2016-2019

Question	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
(Q1) Did you find the project-based learning and teaching activities of the course engaging?	36.7%	58.3%	5.0%	0%	0%
(Q2) Did the course motivate you and gave you a sense of purpose?	33.4%	43.%	21.7%	0%	1.6%
(Q3) In your opinion, did the final project integrate theory and practice?	45%	50%	3.3%	1.7%	0%
(Q4) Did the analytical report help you enhance your critical thinking and problem-solving skills?	45%	46.7%	6.7%	0%	1.6%
(Q5) Did the course help you improve your independent professional judgement?	25%	53.3%	20%	1.7%	0%
(Q6) Did the individual assessments of the course and maintaining the logbook help you improve your capacity to work independently?	23.3%	50%	21.7%	3.3%	1.7%
(Q7) Did the team-work activities help you strengthen your sense of connection, effective working relationship and friendship?	26.7%	36.7%	26.7%	8.3%	1.7%

Most important outcomes of the survey are given below which provide evidence of impact of adopted active learning PPBL approach:

Learning Outcomes: Over 76% of the participants believed that the course motivated them and gave them a sense of purpose. 95% of the students agreed (45% strongly agreed) that the final design project successfully integrated theory and practice. This is a very promising result, given that the alignment between theory and practice is a major goal in PPBL learning. More than 90% of the students found the analytical report helpful in enhancing their critical thinking and problem-solving skills. Positive comments demonstrate that the PPBL approach has influenced, motivated and inspired students to learn:

> *"Challenging quizzes for non-engineering students however once we've grasped the concepts it became easier. I liked the final assessment. It was challenging but very interesting and learned a lot especially working in a group."*

> *"Lectures were engaging for this course (even on a Friday afternoon). Assessment helped to guide students through the coursework. Assistance was provided wherever needed for students struggling to grasp concepts. Overall, one of the most engaging courses completed in my Architectural Design degree."*

Engagement: More than 95% of the students found the PPBL learning and teaching activities of the course engaging. About 80% of students agreed that L&T activities and assessment items improved their independent professional judgement and their capacity to work independently. More than 62% believed that team-work activities strengthened their effective working relationship and friendship. Students also found the hands-on activities and the real-life final design project meaningful. These outcomes suggest that the adopted PPBL has made the course engaging and relevant to students from various backgrounds and different programs, as is evident in students' comments:

> *"The most memorable part was going out and applying/investigating what we were learning in real life situations and projects. Being able to see how what were learning about works and where it is utilised was incredibly helpful and by doing so ourselves we gained a greater understanding of how these structural systems work. I think it would be good to continue sending students out and having them see for themselves how these structural systems work and where they are applied, it provides you with a realistic skill and understanding as opposed to a theoretical one. This is something we can actually use later, after university."*

In order to encourage the students to reflect on their peers' work, group PPBL activities were developed. These collaborative and cooperative activities were successful in improving the students' sense of connection and effective working relationship as is evident in the positive responses to Q7 of the survey in Table 1.

Knowledge retention: The effect of PPBL approach on improving students' knowledge retention, and the relation between the learners' background and their performances in different types of learning activities and assessments have been statistically investigated from two consecutive offerings of 2014 & 2015 (Karampour et al., 2016). Retention of knowledge during the trimester (or semester) and its relation to the assessment items and L&T activities was evaluated from years 2016 to 2020. This was conducted by monitoring students attendance and performance in individual and group activities. It has been found that the performance of school leavers in a problem-solving written exam was greatly enhanced by encouraging them to participate in group hands-on activity, actively supervised by the teaching team. The PPBL approach also proved to have significant effect on improving students' retention rate. In 2014-2015, the failure/non-completion (Grade<4) rate was around 20%. This ratio reduced to 9.1% in 2016, and has been below 10%, since.

Assessments:

Assessment item 1: From 2016 to 2019, this item was run as a traditional paper-and-pencil test. In 2020, this assessment was changed to a problem-solving assignment that included

appropriate items to measure students' understanding and level of skills required for the project-based learning. Table 2 presents the students' (a) participation rate and (b) performance in assessment 1 over the studied period and shows that the re-design in 2020 has improved both.

Table 2: Assessment 1, traditional (2016-2019) vs. re-design in 2020

	2016	2017	2018	2019	2020
Participation rate, excluding deferred attempt (enrolment)	73.9% (131)	67.8% (119)	71.3% (138)	66.7% (163)	80.1% (158)
Average mark	65.0%	64.8%	57.6%	60.1%	78.8%

Assessment item 2: The closed book Multiple Choice quiz was changed to an open book online MC quiz in 2020. The questions were slightly different from previous years and were more in line with the learning outcomes of the PPBL approach. As represented in Table 3, a change from closed book in-person quiz to online open book exam significantly improved the participation rate without major change in the overall average mark.

Table 3: Assessment 2, traditional (2016-2019) vs. re-design in 2020

	2016	2017	2018	2019	2020
Participation rate, excluding deferred attempt (enrolment)	69.9% (131)	68.2% (119)	60.0% (138)	66.1% (163)	79.7% (158)
Average mark	60.0%	55.1%	50.6%	50.8%	46.8%

Assessment item 3: As evident in Q4 of the survey (Table 1), over 90% of the students agreed (45% strongly agreed) that the analytical report improved their critical thinking and problem-solving skills.

Assessment item 4: Based on the learners' response to Q3 (Table 1) of the survey, 90% of the students agreed (45% strongly agreed) that the final design project achieved its goal and integrated theory and practice.

Assessment item 5: In order to inspire students to reflect on their work, each student was asked to keep a logbook of weekly activities and progress. The logbooks were marked twice in the trimester, first time in week 6 (prior to the Quiz) and second time in week 12 (before submission of the final design project). As represented in responses to Q6 in Table 1, over 83% of the students agreed that maintaining the logbook helped improve their capacity to work independently.

Conclusions and recommendation

- The PPBL approach combined with the variety of individual and group assessment items have proven to foster student learning and engagement by linking theoretical knowledge to real-world problems, evidenced by the survey data and the students' qualitative responses.
- Survey results showed that, the most favourite assessment items are the real-life final design project (50% of the votes) and the analytical report (38% of the votes), compared to the written quiz (12% of the votes). This shows that students prefer assessments that are more reflective of a career-based scenario.

- Current results confirm that in PPBL learning, performance-based assessment and portfolio assessment are more appropriate than traditional paper-and-pencil tests. The former methods not only are better measures of the level of understanding and analytical/design skills in a PPBL learning method, but also boost students' participation in the assessment.
- Requiring students to document their information, feelings, experience, reflection and conclusions in a reflective journal can enhance their learning process and outcomes.
- In future, the first two assessment items should be accompanied by L&T activities that are aligned with a problem-based learning approach. These assessments should be properly linked to assessment items 3 and 4 to close the loop of the PPBL method.
- The PPBL method may also be extended to other similar engineering courses that offered to multi-disciplinary group of students from different programs.

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