Project Enhanced Learning in Fundamental Mechanics and Structures Courses

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Introduction

In a traditional Civil Engineering program, fundamental mechanics and structures courses are typically assessed based on a series of problem-solving, hand-calculation assignments, mid-term and final exams, due to their very nature of being theoretical and analytical. Students often follow passively a set of well-defined analysis steps and procedures, as taught by lecturers and tutors, in completing their assessment tasks. Although about 70-80% of each cohort can pass these courses and around 30-40% of the cohort can achieve "Distinction" and above, their retention of knowledge for learning subsequent higher-level mechanics and structures courses has not been found satisfactory. It is to a certain extent attributable to the traditional way of assessment which inevitably limits the students' in-depth understanding of complicated concepts and principles, and lacks necessary connections from the theoretical knowledge to real-world applications. This is despite the efforts made over the years to utilise various types of demonstrations in mechanics and structures courses to enhance student understanding (Guan and Gilbert, 2011; Gilbert, Guan, Qin, and Drew, 2013).

To address these issues, a transition strategy was adopted at Griffith University to shift from wholly traditional to mixed types of assessment including experiential type assessments. This was achieved by implementing a suite of analysis-design projects in the first to third year fundamental mechanics and structures courses offered to Civil Engineering students at Griffith University. Literature shows that, projects provide a context for what students are learning, and if properly structured, can lead them to probing questions and rigorous learning; and requiring students to expand on course material to tackle a bigger problem can encourage them to take charge of their own, self-directed learning (Barroso and Morgan, 2009). Further, these experiential assessments and supporting activities encourage a deep approach to learning (Crawley, Malmqvist, Östlund, Brodeur, and Edström, 2014). Analysis of data obtained from a series of surveys indicates that the project-based assessments introduced in Year 1 (Yr1) to Year 3 (Yr3) mechanics and structures courses are well-received by the students, in terms of enhancing their learning experience, engagement and knowledge retention of the mechanics principles and their applications in the subsequent higher-level mechanics and structural courses.

Analysis-Design Projects

Figure 1 shows a flowchart of the mechanics and structures courses forming an integral component of our Bachelor of Civil Engineering curriculum at Griffith University, and how Yr1 and Yr2 courses serve as pre-requisites for Yr3 and Yr4 courses. Note that 2103ENG, 3103ENG and 6003ENG are design-based courses, and the other four are analysis based.

Carroll (1997) pointed out that for most engineering science courses, students are taught to work on short, well-defined and single-answered problems which illustrate the principles of the course, but bear little resemblance to practical applications; whereas realistic project problems are much longer, not as clearly defined, and may have many solutions. Not unlike the project design of Barroso and Morgan (2009), the projects developed at Griffith University are also more realistic and involved than most hand-calculation assignments. They were designed to develop and assess a different set of skills than assignments and exams, such as deep

understanding, motivation, and critical thinking from design perspectives. Specifically, the projects involve analysing a range of skeletal structures under various design constraints. Students are given opportunities to reinforce their analysis skills by performing numerical analyses (direct or trial-and-error) using general-purpose software package of one kind or the other. Building such a computer analysis experience from foundation years plays an important role in structural engineering education (Romero and Museros, 2002). The projects are submitted as a written report with calculations, justifications and discussions on open-ended questions. The project reports were marked based on (1) problem solving ability, (2) clarity and accuracy in calculation, (3) justification and (4) discussion.

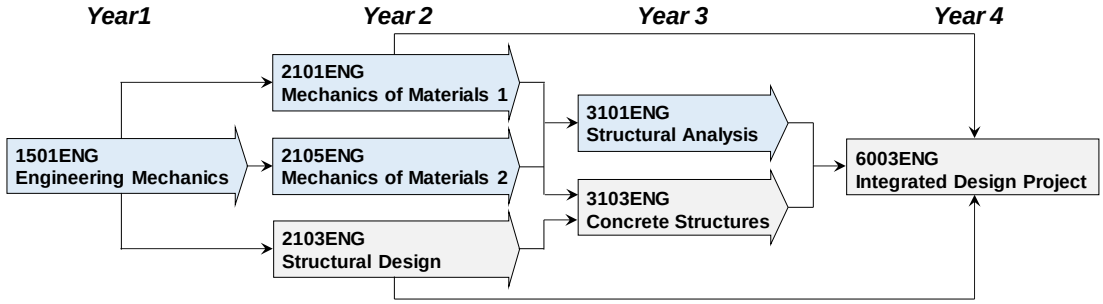

Figure 1: Mechanics and structures courses as part of Bachelor of Civil Engineering curriculum

Relevant analysis-design projects have been implemented, in a staged manner from 2016 to 2018, as part of the assessment tasks in the following Yr1 to Yr3 mechanics and structures courses.

1501ENG Engineering Mechanics (Since 2017)

Design of a truss and *a beam bridge*: Identify, describe and reflect on existing real-life bridges constructed using truss and beam members. An actual truss and a beam are chosen by the students in their residential area, allowing students to self-direct and progress based on their reflection and through continuous feedback from the lecturer and tutors. Students then estimate the load, analyse and design their chosen statically determinate systems to find the axial forces of truss members and internal force characteristics and deflections of beams.

2101ENG Mechanics of Materials I (Since 2018)

Design of a signpost: Determine the lightest and most economical square, rectangular or circular steel tube section to support a cantilevered roadside signpost.

Design of a tension brace: Design an economical tension brace that could resist the specified design load. Identify and explain the potential failure modes (i.e. tension, shear and bearing).

2105ENG Mechanics of Materials 2 (Since 2016)

Design of a cantilever beam and a bridge truss for strength and serviceability: Use SpaceGass software to optimise the design of a cantilever beam and a bridge truss for serviceability (deflection) and strength (stress) limits, and to compare the simulation results against theoretical predictions.

Design of a pressurised storage tank: A pressurised storage tank is to be designed using ANSYS software. Test the accuracy and sensitivity of results with regards to the mesh size, asymmetric modelling techniques and the choice of elements.

3101ENG Structural Analysis (Since 2018)

Design of a gabled-roof portal frame: A gabled-roof portal frame is constructed to resist uniformly distributed wind pressure. Given the specified height and roof angle, determine, using Strand7, a longest span length for this frame to satisfy the flexural, shear and deflection design criteria.

Design and Conduct of Survey

A series of purposely-designed surveys has been conducted to gather the student perceptions on how effective the project enhanced learning, by implementing project-based assessments, have enhanced their (1) overall learning experience, (2) engagement and (3) knowledge retention. Both quantitative and qualitative data were collected from a total of 150 students undertaking one or more of the three mechanics and structures courses, viz., 2101ENG Mechanics of Materials I (Yr2), 3101ENG Structural Analysis (Yr3) and 6003ENG Integrated Design Project (Yr4) in Trimester 1, 2019, on both Gold Coast and Nathan campuses of Griffith University. Students were asked to respond to three questions (as listed in Table 1) by placing 0-5 in the boxes marked by **W** – Learning with a project and **WO** – Hypothetically without a project. The 5-point Likert scale is: 0 – Not at all, 1 – To a small extent, 2 – To some extent, 3 – To a moderate extent, 4 – To a great extent, 5 – To a very great extent. Students' responses were treated as anonymous.

Table 1: Survey question for a typical mechanics and structures course

Course	Question	W	WO
3101ENG *Structural Analysis* ⇩	**Q1. Learning experience:** Assessment tasks in 3101ENG were effective in helping me better grasp and master complicated concepts and principles.		
	Q2. Engagement: Assessment tasks in 3101ENG assisted my learning and engagement by linking theoretical knowledge to real-world problems.		
Subsequent mechanics & structures courses	**Q3. Knowledge retention:** My knowledge gained from 3101ENG has assisted my learning of subsequent mechanics & structures courses.		

Survey Results and Discussions

A survey of the Yr4 Civil Engineering students was conducted on Gold Coast campus. As the duplicated offer of Civil Engineering commenced in 2017 on Nathan campus, two surveys of the Yr2 and Yr3 students were thus conducted on both campuses. The combined survey data from two campuses are summarised in Tables 2, 3 and 4 for Yr2, Yr3 and Yr4 student cohorts, respectively. Survey data for Q1 and Q2 for all relevant courses were collected. For courses undertaken in preceding years, Q3 was also required to be answered. Note that the improved perception (IP in %) is calculated as one-fifth the difference between learning with (W) and hypothetically without (WO) a project, i.e. (W-WO)/5, giving the survey scale being from 0 to 5 at five equal intervals. For example, an IP of 30% for Q1 indicates that the assessment task with a project improved the students' learning experience by 30% compared to the one without (see Table 2). The resulting IPs are also presented separately for Q1 to Q3 and the average IPs for each question are also given.

Table 2: Survey of Yr2 students conducted in 2101ENG course

Course	Question	Response no.	W or WO	Average	Improved perception (IP)			
					(W–WO)/5	Q1	Q2	Q3
1501ENG	Q1	43	W	4.3	30%	30%	-	-
			WO	2.8				
	Q2	43	W	4.4	35%	-	35%	-
			WO	2.7				
	Q3	41	W	4.1	25%	-	-	25%
			WO	2.8				
2101ENG	Q1	9	W	4.6	20%	20%	-	-
			WO	3.6				
	Q2	9	W	4.4	18%	-	18%	-
			WO	3.6				
					Average	**25%**	**26%**	**25%**

Table 3: Survey of Yr3 students conducted in 3101ENG course

Course	Question	Response no.	W or WO	Average	Improved perception (IP)			
					(W–WO)/5	Q1	Q2	Q3
1501ENG	Q1	32	W	4.1	23%	23%	-	-
			WO	2.9				
	Q2	32	W	4.1	27%	-	27%	-
			WO	2.8				
	Q3	30	W	4.1	18%	-	-	18%
			WO	3.2				
2101ENG	Q1	34	W	4.2	23%	23%	-	-
			WO	3.1				
	Q2	34	W	4.4	24%	-	24%	-
			WO	3.2				
	Q3	33	W	4.3	22%	-	-	22%
			WO	3.2				
3101ENG	Q1	52	W	4.5	23%	23%	-	-
			WO	3.4				
	Q2	52	W	4.3	20%	-	20%	-
			WO	3.3				
					Average	**23%**	**24%**	**20%**

Table 4: Survey of Yr4 students conducted in 6003ENG course

Course	Question	Response no.	W or WO	Average	Improved perception (IP)			
					(W–WO)/5	Q1	Q2	Q3
2105ENG	Q1	17	W	3.5	25%	25%	-	-
			WO	2.2				
	Q2	17	W	3.7	25%	-	25%	-
			WO	2.5				
	Q3	17	W	3.5	19%	-	-	19%
			WO	2.6				
3101ENG	Q1	18	W	3.9	22%	22%	-	-
			WO	2.8				
	Q2	18	W	3.8	27%	-	27%	-
			WO	2.4				
	Q3	18	W	3.7	19%	-	-	19%
			WO	2.8				
					Average	**23%**	**26%**	**19%**

Q1. Learning experience

The average IPs for Q1 are 25%, 23% and 23% obtained, respectively, from Yr2, Yr3 and Yr4 student cohorts. These values suggest that students from all the three year levels consistently agree that the analysis-design projects implemented in the fundamental mechanics and structures courses were effective (improved by about 24% overall, averaged from the aforementioned three IPs for Q1) in helping them better grasp and master complicated concepts and principles. Survey on 2101ENG projects also indicates that senior students (Yr3) appreciate more of the project enhanced learning (IP=23%, Table 3) in their 2101ENG course than the current 2101ENG (Yr2) students (IP=20%, Table 2). Both Yr3 and Yr4 students value the 3101ENG project almost equally (IP=23%, Table 3 and IP=22%, Table 4).

For 1501ENG, curriculum and delivery methods were changed significantly in 2017. It is worth noting that academics involved in this course were on a learning curve too and had a potential to make further improvements to the course from 2017 to 2018 incorporating student feedback. In particular, the project brief was made much clearer for the current Yr2 cohort compared to Yr3. Therefore, a much better response from the Yr2 cohort (IP=30%, Table 2) resulted compared to the Yr3 cohort (IP=23%, Table 3). This improved IP can also be attributed to the scaffolding activities and consultation sessions related to the project matters (Gunalan, Gilbert, Guan, Karampour, and Crough, 2018).

Convenors of all the courses listed in Tables 2 to 4 added a specific question to the standard ones in their formal Student Experience of Course (SEC) surveys in 2017 to 2019 - "*The real life project(s) in this course assisted my learning*". The mean values of the quantitative summary of this question, ranging from 4.1 to 4.6 on a 5-point Likert scale, strongly suggest the effectiveness of project enhanced learning. This can be further confirmed by the qualitative responses from the students: *"Projects also helped become quicker at solving each problem", "The given projects help further understand the material", "The FE projects style of questions provoked me to think beyond what the question was simply asking and challenged my understanding of common principles".*

Q2. Engagement

Engagement is reflected in terms of how the analysis-design projects have fostered student learning and engagement by linking theoretical knowledge to real-world problems. Average IPs of 26%, 24% and 26% given by Yr2, Yr3 and Yr4 cohorts, respectively, clearly indicate that the project enhanced learning approach has been positive for students. The overall IP is 25%. Similar to the survey responses for Q1, senior students found more merits in experiential type assessment, substantiated by an IP of 24% from the Yr3 cohort (Table 3) versus 18% from the Yr2 cohort (Table 2) for the 2101ENG projects. Likewise, 3101ENG project also received an IP of 27% from the Yr4 cohort (Table 4) versus 20% from the Yr3 cohort (Table 3). It is worth noting that Yr4 cohort are currently undertaking 6003ENG Integrated Design Project, an integration of fundamental engineering courses, which involves real world design projects (Chowdhury, Guan, and Doh, 2005). Even though some of the foundation courses are design-based, all the mechanics courses listed in Tables 2 to 4 were taught and assessed in a largely traditional manner prior to 2016. As the first cohort of students who have done analysis-design projects in their higher-level courses, this current Yr4 cohort are better equipped with generic skills and the ability to solve real-world design tasks. This explains why their improved perceptions are relatively high.

Students' qualitative responses also speak highly of their engagement with these technically challenging courses: *"Enjoyed working on real life projects as part of a team", "Good practical scenarios (tute exercises and projects)", "Practical questions as well as the project were particularly good", "I like how the FE project related to completing a project in my discipline, how it gets you to think about what is recommended rather than reading what is recommended".*

Q3. Knowledge retention

Note that this question was only relevant to the students to comment on the course(s) that they have already undertaken in preceding years. The average IPs on knowledge retainment are 25%, 20% and 19%, respectively, agreed by Yr2, Yr3 and Yr4 cohorts. This gives an average IP of 21%, suggesting that the implemented analysis-design projects have helped the students to reinforce and strengthen their understanding of the mechanics concepts and principles, which can maximise long-term retention and application of knowledge.

Student comments are also positive about the educational value of these projects in providing a degree of deep learning that will assist their future study of higher-level mechanics and structures courses: *"The real life project really cemented how the content can be used", "The project helped me to consolidate my understanding of the content taught in the lectures", "Real life applications to course were given, and solidified through guest lectures".*

It should be noted that the perceptions of project-based assessments to support knowledge retention, gathered from the Yr3 and Yr4 cohorts, are based on their previous two years of study. On the other hand, the perception from the Yr2 cohort is based on only one preceding year of study. Due to the increased time lapse for Yr3 and Yr4 cohorts, their IPs (20% and 19%, respectively) are comparatively lower than their Yr2 counterpart (25%).

Overall improved perceptions

Summing up all the three questions, it is interesting to note that Q3, Q1 and Q2 are in an ascending order of overall IPs (21%, 24% and 25%, respectively). In other words, project enhanced learning has more impact on improving the engagement and overall learning experience. Although improved perception on knowledge retention is also over 20% when shifting from wholly traditional to mixed types of assessment complemented by analysis-design projects, there is certainly room for further improvement. Given that these projects have just been introduced to 2101ENG and 3101ENG in 2018, some adjustment and fine-tuning will be made in forthcoming offerings. Another aspect worth noting is that, some students were concerned about the time commitment required to complete the projects relative to the weighting of the total marks. Specifically, the project weightings in all the four analysis-based courses vary between 7.5% to 30%. Barroso and Morgan (2009) indicated that the projects must be a minimum of 10% of the final course grade in order for the students to take the experience seriously and gain the benefits from the experience. Balancing the weighting of the assessment items including projects to reflect Barroso and Morgan's findings will be further addressed by relevant course convenors.

Conclusion

In an attempt to enhance the learning journey and outcomes of a whole suite of mechanics and structures courses in an undergraduate Civil Engineering program, experiential assessment practices have been implemented at Griffith University. Relevant analysis-design projects, complementing the traditional type assignments and exams, were developed and assessed in our first to third year fundamental mechanics and structures courses. A series of surveys were conducted, on both University campuses, in Yr2 to Yr4 classes in Trimester 1, 2019. Survey data evidently suggest that this project enhanced learning approach has been positive for students, in all three aspects of the learning experience, engagement and knowledge retention.

Interestingly, based on student responses for 3101ENG, Yr4 students appear to be more appreciative of the transition from wholly traditional to mixed types of assessment with project experience, particularly in the aspect of engagement by linking theoretical knowledge to real-world problems. Whilst iterations of enhancement were made in 1501ENG, the improved perception of the Yr2 cohort is clearly higher than that of the Yr3 cohort for all three questions. This explains why their improved perceptions are relatively high. For course convenors, these observations can facilitate reflective measures to be undertaken to further

tailor and streamline the technical content of the analysis-design projects and matching assessment activities for other mechanics and structures courses. The overall student performance in all these courses also merits comparison in the future between the past offerings without projects and the ones with project experience.

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