Implementing Active Learning Approaches to Enhance Learning for Students with Diverse Backgrounds in a First Year Engineering Course

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CONTEXT
Introduction to Structures *1801ENG*, is a first year engineering course which aims to introduce structural concepts to Architecture and Industrial Design students. The students are from different age groups, cultural and educational backgrounds and bring with them different needs and academic potential. Over the past two years, the teaching team has observed that the majority of the students seem to have adopted a surface learning approach, and thus did not retain the knowledge of the material taught over the course of the semester. Previous researchers have shown that approaches to learning are associated with the students' perceptions of their learning environment Parpala, Lindblom-Ylänne, Komulainen, Litmanen, and Hirsto (2010) as well as different approaches to teaching Trigwell, Prosser, and Waterhouse (1999). It is believed that the passive teaching scheme and the lack of consideration of students' backgrounds in the design of the learning activities has had a negative effect on students' engagement, and has encouraged them to adopt surface learning approaches towards the course material.

PURPOSE
In this study, the effect of collaborative and cooperative forms of active learning on improving students' engagement and retention of knowledge and its relation to the background of the learner is investigated.

APPROACH
The relation between the learners' background and their performance in different types of learning activities and assessments in two consecutive years are investigated herein. The numerical data are presented in form of graphs and tables and the results are validated by formal surveys, performance in the assessments and quantitative and qualitative feedback at the end of semesters.

RESULTS
The results showed that performance of younger students in a problem solving exam is greatly enhanced by encouraging them to study in groups supervised by the teaching team. Teamwork also proved to have a positive effect on the performance of students with *OP*>10 in *MCQ* and analytical report writing assessments. Experiential learning proved to enhance engagement and the retention rate, however allocating extra time to the experiential learning activities had a negative effect on the performance of younger students.

CONCLUSIONS
Based on the current results, some recommendations have been made that can be used for a re-design of the learning activities and assessments of the course. The recommended changes account for students' knowledge background, performance in high school and age. The results also highlighted the significant positive effect of learning activities in the form of competitions on the overall performance of the learners.

KEYWORDS
Students' background, Active learning, First-year engineering

Introduction

Introduction to Structures *1801ENG*, is a first year engineering course engineering which aims to introduce structural concepts to Architecture and Industrial Design students. The students are from different age groups, cultural and educational backgrounds and bring with them different needs and academic potential. This diversity makes it challenging to give them the support and help needed to ensure their chance of success McKenzie and Schweitzer (2001). The teaching activities in the course are comprised of weekly 2 hour traditional lectures and 3 hour problem solving and hands-on tutorials. In *1801ENG* the students are familiarized with simple mechanics concepts such as forces, reactions and equilibrium in the first 5 weeks of the semester. From weeks 6 to 10, the students learn about loads, structural systems and design procedures. Teaching in the final weeks of the semester is dedicated to preparing the students for the summative end-of-semester assessment, i.e. the final design project. This assessment is a comprehensive project which examines the students' ability to implement the learned theories in designing a real-life structure. Over the past two years, the teaching team has observed that the majority of the students seem to have adopted a surface learning approach, and thus did not retain the knowledge of the material taught over the course of the semester. It is believed that the passive teaching scheme and the lack of consideration of students' backgrounds in the design of the learning activities has had a negative effect on students' engagement, and has encouraged them to adopt surface learning approaches towards the course material.

Previous researchers have shown that approaches to learning are associated with students' perceptions of their learning environment Parpala, Lindblom-Ylänne, Komulainen, Litmanen, and Hirsto (2010) as well as different approaches to teaching Trigwell, Prosser, and Waterhouse (1999). Gibbs (2010) indicated that the quality of students is one of the presage variables that makes for quality in learning and teaching. Gibbs argued that students' aspirations, self-confidence and motivations have a stronger influence on their performance in higher education than the scores they bring from high school. Ambrose and Lovett (2014) highlighted the critical role of prior knowledge in learning. Their investigation indicated that in order to create effective learning environments, the teacher needs to evaluate the content, beliefs and skills students bring with them into the course. These studies stress the significant role of the educator in considering the students' background in designing the learning activities. Other researchers have accentuated the effect of active learning in improving students' retention of material (Chickering and Gamson (1987); Felder, Woods, Stice, and Rugarcia (2000)). Bonwell and Eison (1991) provided a summary of literature on active learning which indicates that it surpasses traditional lectures for motivating students for further study and developing thinking skills. Prince (2004) studied different forms of active learning, namely; collaborative learning, cooperative learning and problem based learning (PBL) in engineering education. Their investigation revealed that collaborative and cooperative environments greatly enhanced student engagement, while PBL was found to have little effect on improving student test scores.

Based on the outcomes of published research, it is assumed that adopting active learning strategies and teaching methods while considering students' backgrounds will enhance retention of knowledge, motivation and engagement of students in *1801ENG*. In this study, the effect of collaborative and cooperative forms of active learning on improving students' engagement and retention of knowledge and its relation to the background of the learner is investigated. The data includes statistical results from delivery of the course in two consecutive years. Based on the current results, some recommendations have been made that can be used for re-designing the learning activities and assessments in the course.

Design

In the current investigation, the data from delivery of the course in 2014 and 2015 are analysed and compared. A summary of the alterations made in the learning and teaching (L&T) activities in the two years are presented in Table 1. In 2015 the students were asked to use logbooks to reflect their efforts during the class and studio sessions. The logbooks were marked twice during the semester and feedback was provided to the learners. A design competition was embedded in the group activities in 2014, where the students were allocated in groups to design and make spaghetti bridges in 2014. The bridges were demonstrated and tested in week 11. The assessment plan was similar in both years and comprised of *Q1* (10% problem solving quiz), Q2 (20% MCQ), report (20% deliverable) and the design project (50% deliverable). This activity was related to the truss-analysis component of the Design project. The study is carried out in two sections; *(1)* the learner's background and *(2)* the learners' performance. In the first section, the learners' background and its effect on their performance in assessments and learning activities are studied. In the second section, a comparison is made between students' performance and the active learning strategies adopted in the two years, such as using logbooks and small group activities in the shape of hands-on experiments and design competitions. The influence of each activity in improving students' learning experiences in association with students' backgrounds is analysed and discussed.

Table 1: L&T activities in 2014 and 2015

Item	2014	2015
Number of students in the studio sessions	2 x 40	1 x 128
Preparation for *Q1*	One-to-one	Group activity
Logbooks	No	Yes
Hands-on experiments (experiential activity)	1 week	3 weeks
Bridge design competition	Yes	No
Design Project	Individual	Group

The learners' background

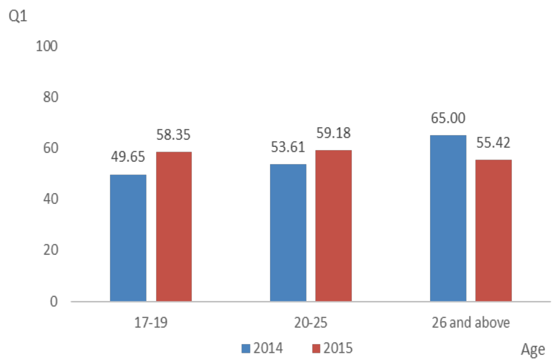
Students' age background

The distribution of student population in terms of enrolment numbers, gender, age group and performance in high school is shown in Table 2. The median age in both years was 19. Students' performance in high-school is presented in the last column. In the case of the intake cohort from outside Queensland, the equivalent overall position *OP* has been calculated.

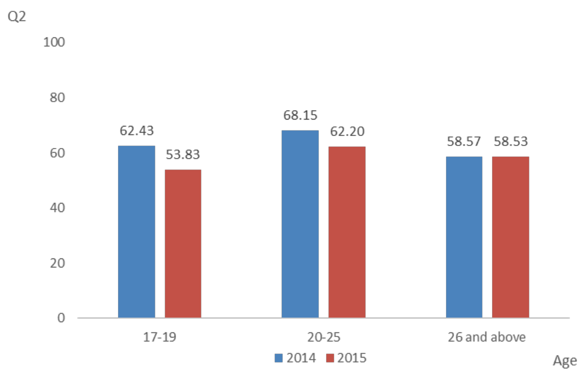
Table 2: Student population

Class	Enrolment	Male	Female	17-19 years	20-25 years	26 years and above	Median OP (or eq.)
2014	76	65.8%	34.2%	47%	37%	16%	10
2015	128	66.4%	33.6%	51%	34%	15%	10

Performance of students from different age groups in Quiz 1 (*Q1*) and Quiz 2 (*Q2*) are presented in Figure 1. Quiz 1 is a paper based assessment which is designed to examine students' comprehension of rudimentary mechanical concepts. Figure 1a shows that in 2015, the students younger than 19 years performed better in *Q1* while mature students performed worse. This can be related to different approaches adopted in 2014 and 2015 in delivering the tutorial classes for preparing students for *Q1* (see Table 1). The mature students seemed to do better when they received one-to-one aid (in 2014), while younger students showed substantial improvement in performance when engaged in group activities preparing for the quiz. Quiz 2 is a multiple choice exam that assesses students' understanding and application of knowledge from some experiential activities. These activities included hands-on experiments which were designed to help familiarise the students with the fundamentals of the mechanics of materials. Students were allocated into groups and performed series of hands-on activities using small-scale test set-up for measuring deflection in beams. The students were asked to change the boundary constraints of the beams as well as length, cross-section and material of the prototypes and reflect on the change in the mid-span deflection of the beam. In 2014, students were given 1 week to conduct the activities whereas in 2015, the activities were carried out over 3 weeks. Figure 1b shows the performance of the different age groups in *Q2*. As shown, allocating 3 weeks rather than 1 week to the experiential activity did not enhance the performance of the younger students and also resulted in a drastic decrease in their scores in *Q2*. It seems that offering longer preparation time without providing effective supervision and mentoring caused the younger students to be less focused in 2015.



(a)



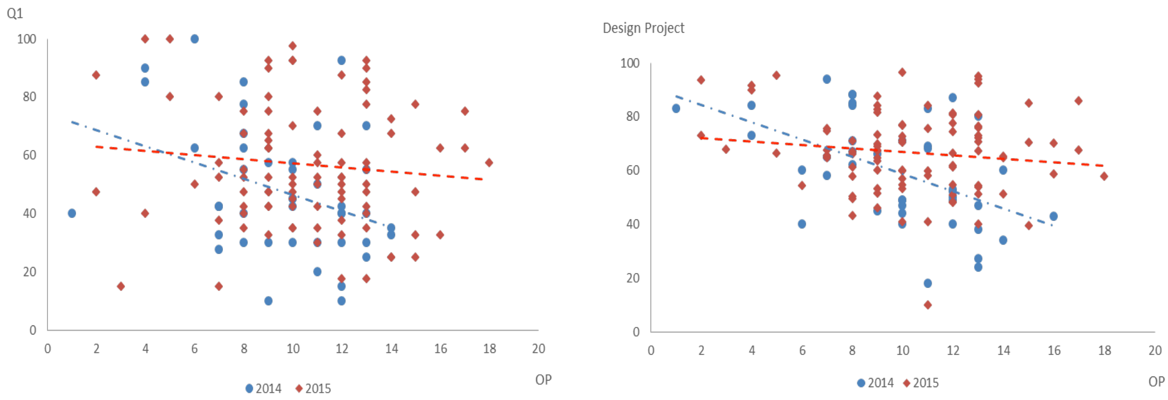
(b)

Figure 1: Performance of different age groups in (a) Quiz 1 and (b) Quiz 2

With regards to hands-on activities, it is worth mentioning that although male students seemed to be more engaged in the activities, no significant differences were observed in the performance of male students compared to female students in *Q2*.

Students' prior knowledge

Students' scores in Quiz 1 and in the final design project are plotted against corresponding student's *OP* in Figure 2 in both years. The median *OPs* of students enrolled in the course in either 2014 or 2015 were equal to 10. The trend lines of *Q1* and the design project data shown in Figure 2, suggest that in 2015 students with *OP*>10 performed better than the similar cohort in 2014. The average slope of the trend line of *Q1* and the final design project in 2015 is about 80% lower than that of 2014. The more uniform performance across *OPs* in 2015 compared to 2014, suggests that the learning activities in 2015 were better tailored to accommodate for the students' knowledge background. The authors believe that using logbooks and encouraging group works in 2015 substantially enhanced student learning, particularly for those with *OP*>10.



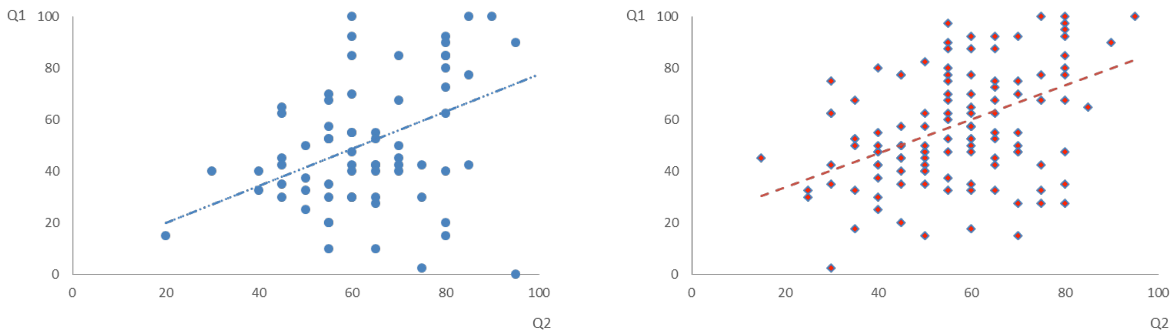
(a) (b)

Figure 2: Students' performance in (a) Quiz 1 and (b) the final design project compared against their *OP*

The learners' performance

Correlation between the learning activities and performance in assessments

Harlen (2006) emphasized the importance of gathering information from formative assessments during the semester and its relation to students' performance in the summative assessment. The relation between students' performance in the formative assessments *Q1* (written quiz), *Q2* (MCQ), analytical report and the summative assessment (design project) in 2014 and 2015 are investigated herein.



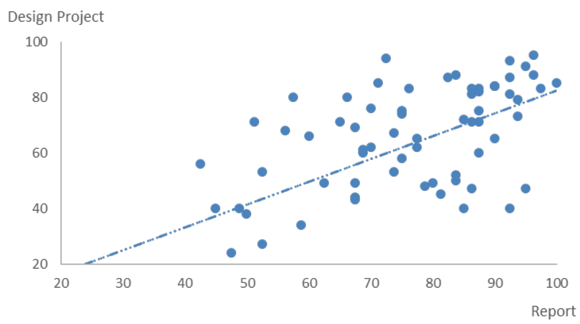
(a) (b)

Figure 3: Correlation between students' performances in *Q1* and *Q2* in (a) 2014 and (b) 2015

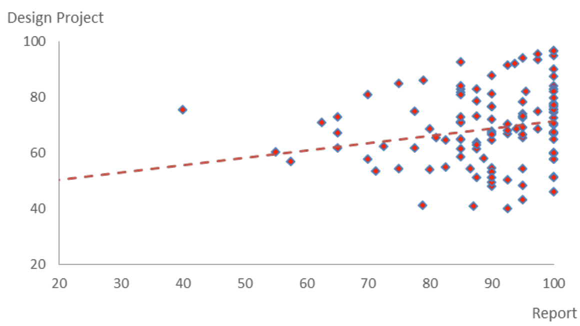
The correlation between students' performances in *Q1* and *Q2* is depicted in Figure 3, which suggests that a meaningful correlation exists between students' scores in the theoretical exam (*Q1*) and the practical assessment (*Q2*) in both years. The slope of the trend line is smaller than unit which suggests there is an improvement in performance in *Q2* compared to *Q1* in both years. It should be noted that the MCQ questions in *Q2*, were carefully designed to assess the learners' comprehension of the theoretical concepts behind the practical activities. Reid, Duvall, and Evans (2007) mentioned that such MCQ components are highly positively correlated with deep learning approaches being adopted by the learners.

The final project has components that assess the knowledge of students from activities related to *Q1* and *Q2*. Plots similar to those shown in Figure 3 were generated (not shown here) to correlate students' performances in the design project and corresponding average performances in *Q1* and *Q2*. Results showed that the students' average performances in *Q1* and *Q2* were significantly better than those in the design project in both years. This can be related to the time gap between *Q1* and *Q2* assessments which were completed in weeks 5 and 8 respectively and the design project which was due in week 14. It is hence understood that additional feedback on *Q1* and *Q2* has to be provided to students, closer to the design project due date. Additionally, it is recommended that assessments *Q1* and *Q2* be redesigned and their importance in the final design project be highlighted to the students.

The relation between grades in the design project and the analytical report in 2014 and 2015 are depicted in Figure 4. The results show that in 2014, the students performed relatively equally in the report and the design project, however in 2015, those who performed well in the report, floundered in the design project. A detailed analysis of the final design project reports revealed that the majority of students in 2015 struggled in the truss-design component of the design project. The truss-design component was embedded in 2014 in a bridge-design activity, but was discontinued in 2015. In this experiential activity, students were assigned to groups and made spaghetti truss-bridges. The bridges were demonstrated and tested, and the winners were allocated bonus marks. The positive correlation between the bridge-design activity and students' performance in the analytical report and the design project in 2014 highlights the significance of student-directed and reflective learning methods in enhancing learning of engineering students.



(a)



(b)

Figure 4: Correlation between students' performance in the design project and the analytical report in (a) 2014 and (b) 2015

Learners' performance and experience

The students' average performances in the assessment activities of 2014 and 2015 are presented in Table 3. The majority of the students in both years were under 19 years old and thus their performance had a substantial impact on the overall grade distribution presented in Table 3. This cohort performed much better in *Q1* in 2015 compared to the previous year, which is attributed to the overall performance of the class in that assessment in 2015 compared to 2014. Using logbooks and encouraging the students to conduct problem solving activities in groups in 2015 also enhanced the performance of that age cohort. In contrast, assigning more time to the experiential activity in *Q2* had a negative impact on the performance of the younger cohort which was reflected in their performance in *Q2*. This may indicate a need to achieve improved balance between the preparation time for experiential learning activity and student reflective process. Also this group did not appreciate the application of logbooks in the early stages of the semester which was observed in the first marking of the logbooks. This had an inverse effect on their performance in *Q2*. However, the younger cohort managed to efficiently use the logbooks later in the semester, and thus performed significantly better in the report in 2015 compared to 2014. In 2015, the students were encouraged to work in groups to prepare the individual report. This group work activity opened many conversations amongst the students and initiated more interaction between the learners and the teaching team. One significant difference between grade distributions in 2014 and 2015 corresponds to the number of students who did not submit all the assessment items, or withdrew from the course. This group is represented by “Other” in Table 3. The lower percentage for this particular group in 2015 compared to 2014 can be related to adopting more active learning approaches in that year compared to the previous year, and consolidates the significance of active learning in improving student retention in the course.

Table 3: Grade distribution

Year	HD/7	D/6	C/5	P/4	F	Other
2014	9.9%	13.6%	21%	30.9%	9.9%	14.8%
2015	7.1%	17.1%	36.4%	24.3%	7.9%	6.4%

The end-of-semester student evaluation of the course (SEC) survey results and description of the questions are shown in Table 4. No significant change in overall student experience was observed between 2014 and 2015. The descriptive responses showed that students in 2015 were unsatisfied with the feedback provided by the teaching team. Given the 70% increase in the number of enrolments in 2015 compared to 2014, less individual feedback was provided to students in 2015 and this contributed to the lower satisfaction rate shown in S*3*. In addition, the comments from students showed that some students were distracted by the experiential learning assessment requirements (*Q2*) which corresponded to the lower *S2* in 2015.

Table 4: SEC survey results

Year	Participation	Question	S1	S2	S3	S4	S5	S6
2014	35.1%	Score (/5)	4.0	3.8	3.9	3.9	4.3	3.9
2015	39.8%	Score (/5)	3.9	3.6	3.4	3.8	4.0	3.8

S1 - This course was well-organised; S2 - The assessment was clear and fair; S3 - I received helpful feedback on my assessment work; S4 - This course engaged me in learning; S5 - The teaching (lecturers, tutors, online etc.) on this course was effective in helping me to learn; S6 - Overall I am satisfied with the quality of this course.

Conclusion and Recommendations

The learners in “*Introduction to Structures*” are from different age groups, and have different cultural and educational backgrounds. Their background, prior knowledge and the learning approaches they adopt affect their performance in the assessments. This study investigated the relation between the learners’ background and their performances in different types of learning activities and assessments in two consecutive years. The numerical data were presented in the form of graphs and tables and the results were validated by formal surveys, performance in the assessments and qualitative feedback at the end of each semester. Based on the current study, the following conclusions can be drawn:

- The performance of younger students in a problem solving written exam was greatly enhanced by encouraging them to study in groups supervised by the teaching team. Teamwork also proved to have positive effect on the performance of students with *OP*>10 in *Q2* and the analytical report writing assessments.
- Allocating extra time to the experiential learning activity without adapting an effective time-management strategy negatively affected the performance of younger students. It is deduced that younger students need better inculcation of how to work in groups.

- Although male students seemed to be more engaged in the experiential learning activities, no significant differences were observed in the performance of male students compared to female students in *Q2*.
- It is suggested that the formative assessments *Q1* and *Q2* be redesigned to better accommodate what is required in the final summative assessment. The results also highlighted the important positive effect of learning activities in the form of competitions on the overall performance of the learners.
- Active learning approaches adopted in 2015 proved to have significant effect on improving students' engagement and retention rate in the course.

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