

Improving Learning Effectiveness for a Third Year Materials Unit

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BACKGROUND

Our recent teaching practice for a third year materials unit is presented in this paper. Because of the large enrolment number (~180) and limited teaching staff, no assignment was given during the whole semester, and full solutions were directly given in the tutorials, which resulted in the problems of low motivation of study and poor performance. In this year's teaching, we attempted a new strategy incorporating active learning techniques, peer learning and statistical analysis.

PURPOSE

The purpose of this study was testing if the learning effectiveness could be improved by applying active learning, peer learning and statistical analysis.

DESIGN/METHOD

In the teaching for the tutorials of this unit, active learning techniques were attempted. Handouts with gaps were given in the tutorial classes to promote active thinking. Since solving these questions requires consulting engineering charts and tables, there will be differences from person to person. The students were asked to attempt the questions and send the result by email. They were also encouraged to form groups and learn from peers. The results being received were analysed statistically and the distribution was released to the students. There are potentially two benefits: 1) this approach helps the students to derive the correct answer; and 2) this approach gives the students a direct sense about the typical variations of the answers to an exam question, and helps them understand the variations in engineering.

RESULTS

It is shown from our study that the students were more actively engaged with the learning process and became active thinkers, compared to the previous years. The learning outcomes were significantly improved, which was evidenced by the exam results and the student evaluations.

CONCLUSIONS

Active learning can significantly improve the learning effectiveness of engineering units. By utilising peer learning and statistical analysis, students can also learn the variations in the real engineering practice, and team work skills. Thus, they will be more prepared to become professional engineers.

KEYWORDS

Active learning, peer learning, statistical analysis

Introduction

Engineering students are satisfied with the quality of their subjects provided that clear learning outcomes and expected standards were given, the teaching helped them to learn, valuable graduate attributes were developed, the assessment allowed them to demonstrate what they have understood, the relevance of their subject to their degree could be seen, staff were responsive to feedback, their prior learning prepared them well, they could understand their teacher, and the faculty infrastructure was seen to be supportive (Calvo *et al.*, 2010).

Teaching engineering subjects is facing increasing challenges as the classes are rapidly growing over the years. In the literature, many innovative methods have been reported to improve student motivations. Mazzolini *et al.* (Mazzolini *et al.*, 2012) employed interactive lecture demonstrations to improve the conceptual understanding of resonance in an electronics course. El-Sawy and Sweedan (El-Sawy & Sweedan, 2010) discussed the innovative use of computer tools in teaching structural engineering applications. Barber and Timchenko (Barber & Timchenko, 2011) used student-specific projects in a computational fluid dynamics course for improving the student engagement.

Materials 337 is a third year core unit for the mechanical engineering students at Curtin University. The enrolment number for this unit varies from year to year but is usually very large (over 180 in 2012). The teaching pattern of this unit includes a weekly two-hour lecture, a one-hour weekly tutorial, and two labs.

The sequence for the tutorial teaching is shown in Table 1, as seen from which a wide range of topics, e.g. failure, fatigue, and thick cylinders, are covered. Most of these engineering problems are quite time-consuming and challenging.

Table 1: Sequence of tutorial teaching

Tutorial	Main topics
1	Mohr's circle; static failure theory
2	S-N plot
3	Fatigue with stress concentrations
4	Miner's rule
5	Goodman line
6	LEFM
7	Castigliano's theorem
8	Buckling
9	Non-rotating cylinders; compound cylinders
10	Compound cylinders; failure theories

For a problem-based engineering subject, tutorial problems are assigned to build skills in the procedures taught in lectures. Thus, tutorials are a very important component in an engineering unit.

During the past years (to 2011), at the first lecture, a student survey was conducted to collect the student opinions on the delivering of this unit. One of the questions was about the most effective way of learning, as shown in Figure 1, along with the corresponding responses. Interestingly, the percentage of the students who feel they learn the most during the tutorials

increases while that of the students who believe attempting the tutorial questions by themselves decreases. This indicates that an increasing number of students rely on the tutorials to achieve their learning outcomes. Another question about the delivering method of tutorials and the corresponding responses are shown in Figure 2, from which it is clearly shown that since 2009, the majority of the students (around 2/3) voted for going to the full solutions of the tutorial questions, so that they felt they could learn most effectively. This finding is in good agreement with Summit and Venables, who found that students frequently miss tutorial classes and those who do attend often come ill-prepared, or are content to do little while waiting for the answers to be given (Summit & Venables, 2011). It can be concluded that tutorials are the most important component in the learning of this unit but often overlooked.

Q9. Where do you normally learn most about the unit's content?

- A – During the lectures
- B – During the tutorials
- C – During the laboratories
- D – Attempting the tutorials myself
- E – Attempting past exam questions myself
- F – Don't know / other answer

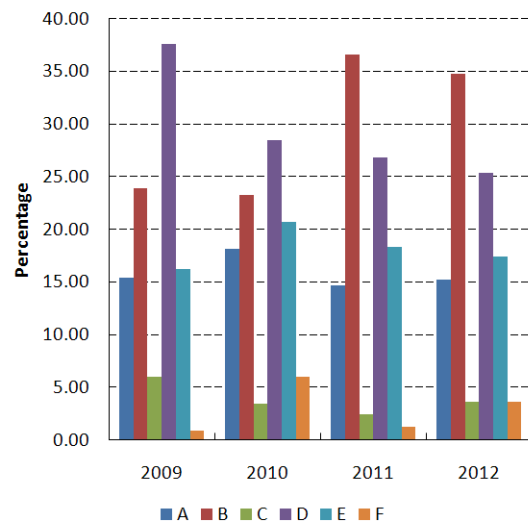


Figure 1: Responses towards the most effective way of learning

Q7. In the tutorials, what format would you prefer? *As background, experience shows that very few students attempt the tutorial questions prior to the tutorials.*

- A – Go straight through the tutorial answers.
- B – Pick a random tutorial question, wait 15 minutes for students to attempt the question, then go through the answer.
- C – Pick a past exam question (not on tutorial sheet) and go straight through the answer.
- D – Pick a past exam question (not on tutorial sheet), wait 15 minutes for students to attempt the question, then go through the answer.
- E – Don't know / other answer

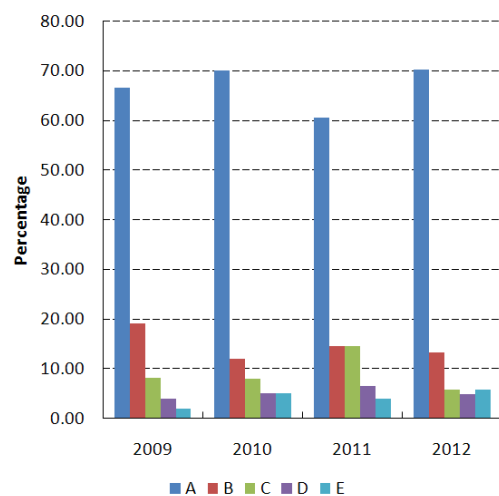


Figure 2: responses towards the delivering method of tutorials

During the past years (~2011), the tutorials were delivered in a lecture mode. In a typical tutorial, one or more tutorial questions were chosen and the full solutions were worked out on the white board. The full solutions to all the tutorial questions were posted to the blackboard and students were asked to attempt them in their own time. However, because of the large enrolment number and limited teaching staff, no assignment was given during the whole semester. Thus, most students did not practise the tutorial questions but only read the solutions. This resulted in the underestimation of the difficulty level. Since all the tutorial questions and solutions were readily available online, it was found that lacking interests and motivation in attending the tutorials. The learning outcomes were unsatisfactory, which was evidenced by the exam results.

This paper reports a new teaching strategy we attempted in 2012 by incorporating active learning techniques, statistical analysis and peer learning.

Method

In order to strengthen the teaching of the tutorials, in 2012, we implemented a new strategy by incorporating active learning techniques, peer learning, and statistical analysis. Active learning is generally defined as any instructional method that engages students in the learning process. In short, active learning requires students to do meaningful learning activities and think about what they are doing (Bonwell & Eison, 1991). Although it is well known that active learning is important to achieve effective learning and teaching (Felder & Brent, 2009) and it promotes both short-term and long-term learning (Prince, 2004), it is often overlooked nowadays, especially as the class sizes grow larger and people are more focused on on-line teaching. We found that with the advancement of technologies, e.g. iPad, etc., the students became less active in learning. They often expected that all the teaching materials would be readily online and they could always access them later. In the tutorials, activities were arranged to force the students to think actively. The arrangement of a typical tutorial class is shown in Table 2. One particular technique that we found useful was using handouts with gaps. According to Cornelius and Owen-DeSchryver (Cornelius & Owen-DeSchryver, 2008), students who only got partial notes got higher exam grades, higher course grades and higher marks on conceptual questions that required mastery of material beyond definitions. As an example, a tutorial question about Goodman line is given in Figure 3. Part of the handout sheet for this tutorial question is given in Figure 4.

Table 2: Arrangement of a typical tutorial class

Time	Activity
10 minutes	A brief review of lecture
15 minutes	Partial solution to an example question
20 minutes	Student exercise
5 minutes	Closure

In addition to these in-class activities, the students were encouraged to work on more tutorial questions in their own time. Since solving these questions requires consulting engineering charts and tables, there will be differences from person to person. During the teaching of the tutorials, we did not give full solutions. The students were asked to attempt the questions and send the result by email. They were also encouraged to form groups and learn from peers. The results being received were analysed statistically and the distribution was released to the students. There are potentially two benefits: 1) this approach helps the

students to derive the correct answer; and 2) this approach gives the students a direct sense about the typical variations of the answers to an exam question, and helps them understand the variations in engineering.

4. The propeller and shaft of an aircraft engine are shown schematically in Figure 4. The propeller has a mass, m , and generates a forward force, F , relative to the aircraft at a constant rotational speed of N rpm. The shaft has a diameter, d , where it joins the propeller and increases with a fillet of radius, r , to a diameter of D at a distance, L , from the propeller centre of mass. The shaft transmits a power, P , to the propeller.

- (a) Show that the effective mean stress, σ_m , and alternating stress, σ_a , at the fillet can be given by the following:

$$\sigma_a = \frac{32mgL}{\pi d^3} K_{f(b)} \quad (4 \text{ marks})$$

$$\sigma_m = \frac{2F}{\pi d^2} K_{f(a)} + \sqrt{\left(\frac{2F}{\pi d^2} K_{f(a)}\right)^2 + \left(\frac{480P}{N\pi^2 d^3} K_{f(t)}\right)^2} \quad (8 \text{ marks})$$

where $K_{f(b)}$, $K_{f(a)}$, and $K_{f(t)}$ are the fatigue stress intensity factors for bending, axial, and torsional loading, respectively.

- (b) Estimate the factor of safety for the following conditions: $d = 40$ mm, $D = 50$ mm, $r = 4$ mm, $L = 200$ mm, $F = 50$ kN, $m = 500$ kg, $P = 40$ kW, and $N = 3000$ rpm. Assume the shaft to be made from commercially polished steel with an ultimate tensile strength, S_u , of 1200 MPa. (Keep two digits after decimal point) (8 marks)

(Total 20 Marks)

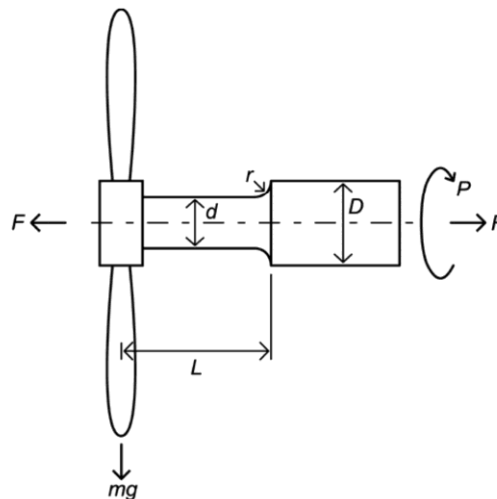
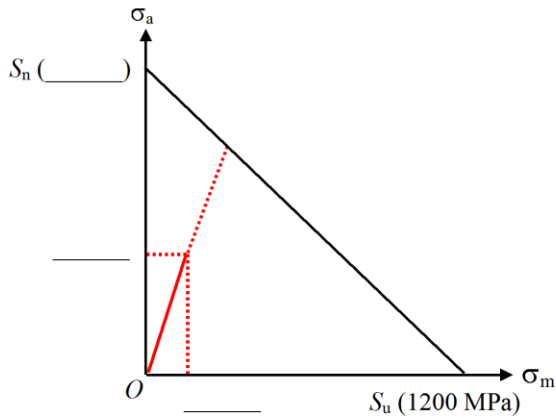


Figure 4

Figure 3: A tutorial question about Goodman line



[1 mark]

We can obtain the following equations:

(i)

[1 mark]

(ii)

[1 mark]

Solving these equations gives:

$\sigma_m =$ _____

[1 mark]

Factor of safety = _____

[1 mark]

Figure 4: Part of the handout sheet for the tutorial question about Goodman line

The distribution of the final answer to the Goodman line problem is shown in Figure 5. The results show a great range of the solutions obtained by the students. The students were fed back with the statistical analysis result and asked to review their solution procedures. Many students found some mistakes at this second attempt. The overall approach is summarised in Figure 6.

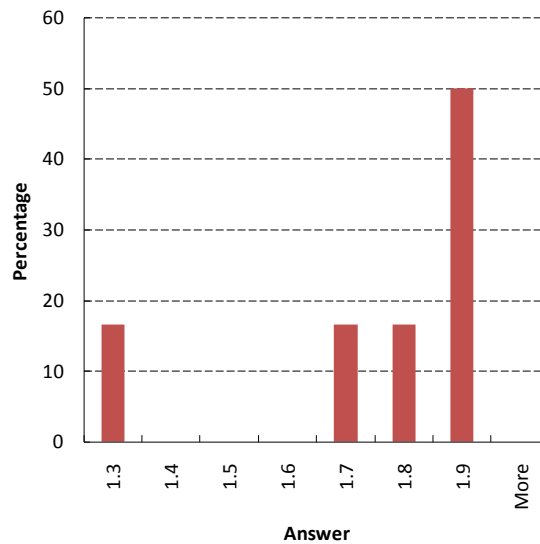


Figure 5: The distribution of the final answer to the Goodman line problem

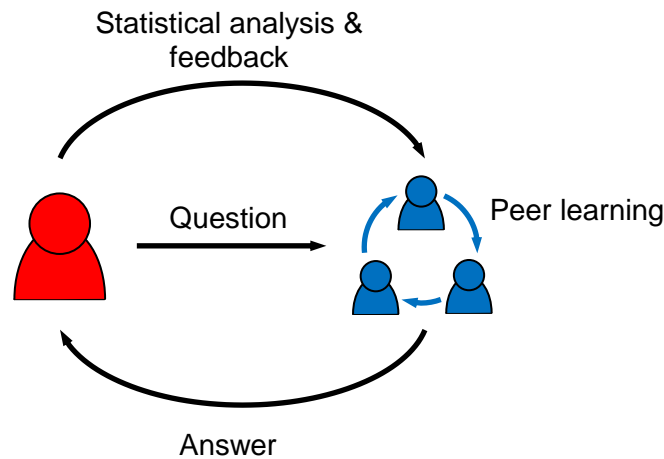


Figure 6: The overall approach

Results

From the class observations, it was found that the students were more engaged with the tutorials and the learning was more effectively. Thus, it was postulated that the method helped the students better achieve the learning outcomes. According to James (James, et al., 2002), three objectives for higher education assessment are: assessment that guides and encourages effective approaches to learning; assessment that validly and reliably measures expected learning outcomes, in particular the higher-order learning that characterises higher education; and assessment and grading that defines and protects academic standards. For these reasons, a comparison of the final exam results of the past four years were made to validate the effectiveness of this approach.

The full mark of the final exams was 60. First, an analysis of the distribution of the marks was made, as shown in Figure 7. It is shown that the marks from 2009 to 2012 are mostly normally distributed except 2011, which shows an extremely high peak around 48/60. This is because for some reason, the exam questions in 2011 were all original tutorial questions. For a problem-based engineering subject, the high pass rate and average mark did not imply

that excellent learning outcomes were achieved. Thus, the data in 2011 were excluded from the further analysis.

The pass rates and average marks of the final exams in 2009, 2010 and 2012 are shown in Table 3. It is seen the pass rate of 2012 is significantly higher than those of 2009 and 2010, jumping from less than 60% to more than 80%. Similar trends are seen for the average final exam mark. The pass rates and average marks of the whole unit in 2009, 2010 and 2012 are shown in Table 4. It is seen the pass rate of 2012 is significantly higher than those of 2009 and 2010, reaching 88.76%. Similar trends are seen for the average total mark for this unit. It can be concluded that the performance of the students was consistently well through the semester, compared to the previous years.

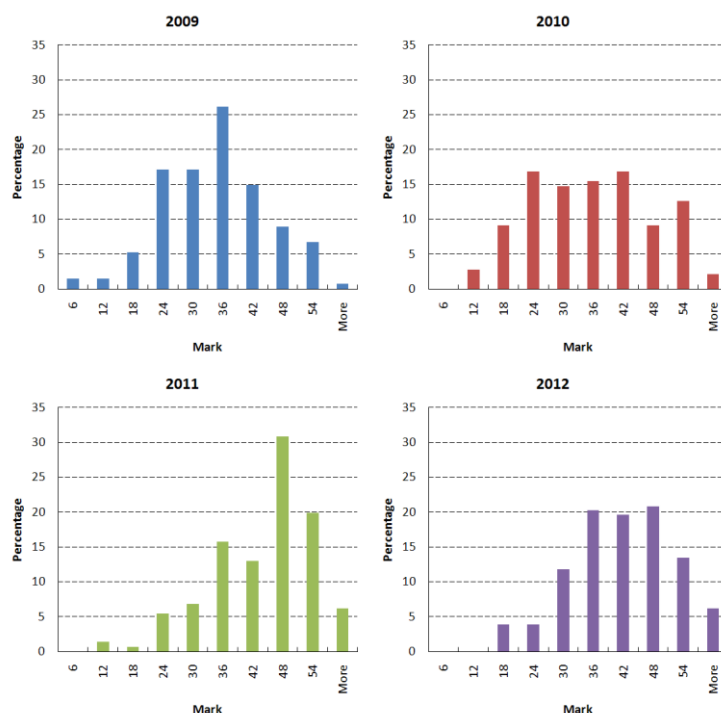


Figure 7: Distribution of final exam marks from 2009 to 2012

Table 3: Final exam pass rates and average marks in 2009, 2010 and 2012

Year	Pass rate (%)	Average (out of 60)
2009	58.21	31.83
2010	56.34	33.05
2012	81.46	38.99

Table 4: Unit pass rates and average marks in 2009, 2010 and 2012

Year	Pass rate (%)	Average (out of 60)
2009	74.81	58.96
2010	72.54	59.31
2012	88.76	64.04

Conclusions

An approach for enhancing the teaching and learning of a third year materials unit based on active learning, peer learning and statistical analysis is presented in this paper. It is shown from our practice that active learning can significantly improve the learning effectiveness of engineering units. By utilising peer learning and statistical analysis, students can also learn the variations in the real engineering practice, and team work skills. Thus, they will be more prepared to become professional engineers. The effectiveness of this approach has been evidenced by the improved exam results.

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