Title: Improving engineering education using research informed active learning methods.

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OVERVIEW

Overview, Aims and Context

This project aimed to embed aspects of active learning, based on the findings of the Carl Weiman Science Education Initiative (CWSEI) in Vancouver in a year 2 fluid mechanics module. It uses techniques used in large lecture environments based on the idea that education is more about training the brain to think in particular ways rather than filling a vessel with knowledge (Weiman 2012).

Description

A visit was arranged to UBC in Vancouver to spend a week shadowing a range of academics and teaching fellows from the CWSEI. From this visit, a number of specific teaching methodologies were identified and then incorporated into a semester 2 module in Fluid Mechanics and Thermodynamics. The three specific activities that were used were:

- Pre-class reading and preparation work, with online quizzes delivered via Blackboard
- In-lecture worksheets and active learning tasks
- Audience response devices to engage students in active learning in seminars.

Ideally, the use of audience response devices should have taken place in the large lecture, but funding was not available to purchase enough devices for 108 students.

A number of other techniques were observed at CWSEI, including two-stage exams and specific methodologies for use in lab classes, but these were not replicated in this project

Design

It was originally intended to employ students to act as learning assistants during this module, specifically to facilitate worksheet activities in the large lecture, but it was not possible to get volunteers from a suitable student cohort.

Clickers were procured from Promethean (ActiVote), primarily based on cost, and particularly on the availability of used devices at much below the recommended price. Based on the funding available, 57 clickers were purchased, together with a license for the ActivStudio software.

Having implemented pre-class activities, in-class worksheets and clicker based seminars, the clickers were also used to gather student feedback on the active learning activities that were used during the module. Overall module performance has also been evaluated, although this is the first instance of this particular module, it having been changed from the previous delivery as a result of revalidation.

As well as overall module performance, one of the objectives of this project is to improve the understanding of materials, and thus improve retention of material beyond the end of this module. This cannot be effectively evaluated until final year, when these students will complete a module that follows from this one.

RESULTS

Findings and Conclusions:

Students were overwhelmingly positive about the three main active learning techniques that were employed. When asked about whether they found clickers useful in terms of helping them learn, 60% found them very helpful, 20% found them helpful, and none responded that they were not helpful at all. For pre-class assignments the results were identical and for worksheets in lectures, 67% found them very helpful, 13% found them helpful and 7% found them not helpful at all.

When students were asked what the most useful learning resource was, the worksheets in lectures received 48.4% of the votes, with pre-class assignments and lectures receiving 12.9 each, problem sheets 9.7%, seminars 6.5% and the text book 3.2%. In terms of the least helpful activities, the textbook at 58% and the lectures at 16% were the highest.

Specifically about clickers, Only 3% of students thought that the use of clickers throughout their programme, for a combination of attendance monitoring and active learning would have a negative outcome. All students would welcome clickers for active learning activities, but a small number (<10%) did not like the idea of attendance monitoring using clickers. The most useful aspects of the clickers were feedback to staff (30%), more active learning activities (27%) and feedback to students (21%). Attendance monitoring and more fun were the least important activities.

Overall module performance is hard to evaluate. The previous module, which was 10 credits rather than 20, has historically had relatively high failure rates, and is recognized as one of the more difficult topics within mechanical engineering. The last 3 years have been 29.6%, 22.2% and 15.9% failure rates at the first attempt by Mechanical Engineering students. The same cohort of students had a failure rate of 25.2% this year. The mean mark in the last 3 years has been 47%, 54% and 52%. The mean mark this year is 54%. The students achieving the higher scores has increased, with 7% gaining above 80% compared with none in 2015-16 and 15% getting over 70%, compared with 14% in 2015-16. Clearly active learning will only have an effect on students who are engaged with the material, so it is possible that the failure rate is not significantly improved while those who are engaged can do better than before.

In terms of engagement, 14 students attempted 12 or fewer of the 18 pre-class quizzes. These students averaged 37% in the module. and 64% of them failed the module. In terms of attendance, those who attended less than 40% (n=19) of sessions averaged 39.5%, and 58% failed the module. For those who attended between 40% and 80% (n=58) of sessions, they averaged 52.3%, and 22% failed. For those who attended more than 80% (n=30) of the classes, they averaged 58.3%, and 23% failed. Engagement levels are difficult to evaluate year on year, as cohorts change significantly. Year 2 often sees lower levels of attendance and engagement than year 1 or final year. In a previous year, where good attendance data are available for the predecessor module, the number of students attending more than 80% of the classes was below 10%, while this year it was 28%.

In conclusion, it has not been possible to show significant learning improvements using the active learning methods employed in this module in terms of overall performance, but the number of students scoring higher than 80% has increased and the levels of attendance have also shown an increase. Students have appreciated the active learning activities, stating that they have helped them learn, and the module feedback has been very positive, with responses well above the University average.

EVALUATION

Reflective Commentary

By engaging with the literature, specifically around active learning in science and engineering disciplines, and by immersing myself in another University teaching context for a week, it has been very clear that the methods that have been shown to work are relatively simple, but implemented effectively. As is well understood from cognitive science and from pedagogical research, one of the most important roles of education is to change the ways that students think, by giving them challenging tasks, and by guiding their thought processes such that they develop the thought patterns of experts (Ericsson and Pool 2016).

I have found the activities relatively simple to generate and facilitate. Blackboard is easy to use to develop weekly quizzes based on pre-class activities, and has been very effective at increasing engagement. I believe that giving a small number of marks to these activities has both improved engagement and also increased attendance. The in-class worksheet activities have been varied. Sometimes these were printed and handed out, other times they were activities presented on-screen. My impression was that the pre-printed worksheets were appreciated more, and engaged with more by students.

One aspect that I think I could improve on for the next delivery of this module is to spend some more time reflecting on the specific activities in each class. With the pressure of delivering a new module, sometimes it was easy to put together activities that were based on the content or the tutorial sheets, while with more thought about the activities, there are probably some that could be made more strategic in terms of learning. The ethos of the CWSEI is that the first task in any learning task is to identify the thought processes of an expert, and to design the task to train the student to test and develop the expert thinking patterns. To apply this approach more thoroughly to both the pre-class work and the in-class activities will be the next step in the development of this module.

In terms of clickers, I did not have enough handsets to give them out permanently to students, so it was not possible to look at individual responses. I tried to structure the seminar classes that used clickers to lead students through a topic in the way that I (an expert) think through the problem, talking it step by step and asking questions on the way through. I have learned a lot about how best to use clickers, with the choice of follow up activity dependent on how the students have answered a question. For example, one of the follow up questions, based on Eric Mazur's peer instruction method, is to ask students to answer a question, then ask them to discuss with their colleagues and answer again. This only works if a significant proportion of the class have understood the question. If most students have not grasped the relevant concepts, the better follow up is for the tutor to re-explain the concept, or give a key clue, and then re-ask the question. The peer instruction method is

very effective where students have grasped at least some of the concepts, as they have to articulate their understanding to each other.

Overall, I believe that the active learning methods have resulted in improved learning. While module performance data have not significantly changed, engagement has been better than is typical of a year 2 module. It may be the case that conceptual understanding is improved, but the specifics are difficult to ascertain based on the assessments that have been used. I intend to further develop these techniques through this and other modules.

Student Engagement:

I felt that the pre-class assignments and quizzes were quite useful as they ensured that you were reasonably up to date with the material.
I think the worksheets in lectures were the most useful as it meant we were all kept stimulated during the lectures and made them much less boring.
The clickers in the seminars were a very good way of highlighting any issues. This meant that they were quickly and easily addressed.

I think that these, along with the tutorial questions, greatly improved on my learning experience and I would love more lecturers to adopt them as new teaching techniques.
Jonathan Davis, year 2 Mechanical Engineering

On refection I found that the Pre- class assignments and quiz were beneficial to the development and understanding of the MEC358 module, however I feel that they did not provide a sense of belonging. In terms of the worksheets within the lectures they had a big impact in developing a strong exam technique and they also provided a sense of belong through the interaction with the lecturer. Finally, the clickers in the seminars are a great idea in my opinion as they help me gain an understanding my knowledge on the current topics on a fortnightly basis. Again they provide me with a sense of belonging when interacting with other class mates. I would also like to make note that I found the tutorials very helpful however, I would heavily advise to other students that you should complete them throughout the year and not at the last minute.
Oliver Hermon, Year 2 Mechanical Engineering

Learning Environment and Engagement:

My view is that learning takes place in the mind of the student, and that the design of physical spaces are much less important than the design of appropriate activities. It is nearly always possible to design activities that help students to start to think more like experts, and to work within the constraints of the learning spaces.

Learning spaces can make some activities easier, and can create a more enjoyable or more open environment, but there are much more significant areas where our teaching can be improved. Consistency is important, where students understand how they are going to be taught, and what sort of activities they are expected to take part in. I believe that a consistent approach throughout a school or programme would do more to engage students and facilitate learning than changes in physical spaces.

In terms of technology, clickers are an excellent way to deliver active learning activities, and especially 2-way communication about learning between staff and students. The provision of clickers to all students would be a huge advance that would enable (given clear direction, training and approach) a consistent system of active learning in both large and small classes.

Impact

With the pilot scale approach taken in this project, and the year to year variability in module cohorts it is difficult to assess the impact of this project on the students directly. It has certainly impacted my own teaching methods, I believe for the better. I have successfully bid for funding to provide clickers for all of year 1 students in 2017-18, and we are currently working on a strategy to enable this.

STRATEGIC DEVELOPMENT

Transferability

The simple activities that have been tried have all been successful and most are possible on any module. Students have indicated that pre-class assignments result in them doing more wok outside of class than they would otherwise do, and facilitate both higher levels of engagement and monitoring of that engagement. In class worksheets or activities also facilitate better engagement and were well received by students. The use of clickers has the potential to be transformative, but requires further investment to enable this to happen.

One of the keys to impact that was observed in the Vancouver experience is the consistency of approach taken by staff. All used worksheet activities and clickers in class, and also used pre-class assignments. Most also used weekly homeworks. While the culture of University is a little different than in the UK, it is clear that the uniformity of the approach results in a consistent expectation from students and acceptance of the methods of teaching.

Dissemination (internal and external) (School and Faculty briefings, workshops, resources developed)

SUPPORTING INFORMATION

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