Improving Fluid Mechanics Instruction using State-of-the-Art CRS

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Abstract

This case study explores the use of a new, low-cost, state-of-the-art Classroom Response System which allows students to use their mobile devices (phones, tablets, laptops) to respond to a variety of numerical, multiple-choice, short-answer and open-ended discussion questions posed during face-to-face workshops. In order to allow sufficient time to fully engage with the workshop activities traditional lectures were revised and the classroom lecture was *flipped*. Students worked through narrated lecture material (*hand-e-lectures*) online, prior to attending the workshops. CRS was included as part of the *hand-e-lecture* content and feedback from this was incorporated into the workshops. Workshops extended the *hand-e-lecture* content by including a variety of carefully designed, engaging activities (many were group activities) that used CRS questions to facilitate discussions, problem solving and case study analysis to enhance student cognition. Overall, the new flipped lecture and CRS teaching format demonstrated high levels of student engagement, motivation and attendance.

Keywords: classroom response systems; Top Hat Monocle; flipped learning; hand-e-lecture.

1 Introduction

Much of the pivotal engineering education research in the last two decades promotes student-centred learning and active learning principles. These principles recognise that when students are actively engaged with their learning, they are much more likely to understand the concepts. The more involved and engaged the student is, the greater his or her level of knowledge acquisition and general cognitive development (Smith et al., 2005) and engagement in higher-order thinking tasks such as analysis, synthesis, and evaluation (Bonwell and Eison, 1991). Biggs (2003) maintains that the way to narrow the gap in understanding between students is to involve them in activities that are engaging and require them to use higher-level cognitive processes. Student engagement is critical for student achievement, retention and success (Dunn et al., 2012).

Research indicates that the use of classroom response systems (CRS) is associated with positive educational outcomes by fostering student engagement and by allowing immediate feedback (Bruff, 2009). Traditional Classroom Response Systems (CRS) are instructional technologies that allow instructors to rapidly collect and analyse student responses to questions posed during class (Bruff, 2009). Traditional CRS rely on special hardware, often generically called clickers, to enable students to engage in voting. Typically, students are presented with a question and a small number of multiple-choice answer options, and students vote for one of the options using the electronic hardware (clickers). The instructor can then display the students' responses, provide feedback and facilitate class discussion regarding the responses. This type of rapid feedback is an ideal form of assessment (Brown, 2004) as it is positioned close to the leaning. Using a CRS to engage students has advantages over many other methods, such as raising hands, because the interaction is anonymous (Beekes, 2006; Guthrie & Carlin, 2004) and so students do not fear being wrong in front of their peers or the instructor (Wood, 2004). Importantly, this means that the use of a CRS allows instructors to engage students who otherwise remain disengaged, such as students with 'lower class standing' (Trees & Jackson, 2007) or students self-identified as reluctant participators (Graham et al., 2007).

The use of CRS allows instructors to provide immediate formative (and, in some cases, summative) feedback, particularly in large classes (Dunn et al., 2013). Feedback is the 'most powerful single influence' on student achievement, and providing timely feedback is one of the main support conditions for student learning to take place (Gibbs and Simpson, 2004). CRS have been shown to improve student learning outcomes by encouraging student engagement with the course content, instructors and student peers (Bartsch & Murphy, 2011; Dunn et al., 2012). Research has indicated that CRS make classrooms more engaging for students, improve student participation and interaction, improve cognition and retention, and can even improve grades (Bakrania, 2012). Including effective active learning strategies is fundamental to providing a successful engineering education (Toto & Nguyen, 2009). For these reasons, the use of CRS has great potential for improving student learning outcomes in all teaching areas.

The pedagogical advantages of using a CRS occur at a higher level of learning (metacognition) as well as at more basic levels (Barnett, 2006; Elliott, 2003). Importantly, using a CRS empowers students to evaluate their own performance (Graham et al., 2007) and to monitor their own understanding of content throughout the course. As a result, the use of a CRS has been shown to increase students' long-term retention of knowledge (Kaleta & Joosten, 2007; Crossgrove & Curran, 2008; Miller et al., 2003) and to increase student achievement (Kyei-Blankson et al., 2009; Mayer et al., 2009). A further pedagogical advantage is that the use of a CRS can provide immediate feedback to the instructor about specific topics where students lack sufficient understanding (d'Inverno et al., 2003) so that more or less instruction can be delivered as appropriate (Koppel & Berenson, 2009). Some instructors have also incorporated CRS into assessment activities (Alexander et al., 2009). In addition, using a CRS is a useful method for implementing peer instruction (Mazur, 1997) which has been shown to increase mastery of conceptual reasoning, and agile teaching, where questions are used to teach and to inform the direction of the lecture rather than to test students (Beatty, 2006).

The ability of a CRS to provide immediate and quality feedback to both students and instructors, particularly in large classes, is highly desirable. It is vital that the device used to deliver student responses is user-friendly, reliable and inexpensive; the sustainability of the system for instructors and staff will determine its long term use. Many traditional CRS only allow students to answer simple multiple-choice type questions. Unless these types of questions are well designed, they may not allow students to demonstrate their depth of knowledge or understanding, or to develop higher-order thinking skills such as analysis, synthesis, and evaluation (Beatty et al. 2006a). This study explores the use of a new, low-cost, state-of-the-art CRS (Top Hat Monocle) which allows students to use their mobile devices (phones, tablets, laptops) to respond to a variety of numerical, multiple-choice, short-answer and open-ended discussion questions posed during face-to-face workshops.

While CRS has been used for well over a decade and been shown to successfully improve student engagement and participation, a number of studies have also identified that its use could potentially mean that less material is able to be covered in lectures (Dunn et al, 2012). Toto and Nguyen (2009) recognised that it is very difficult to continue to cover the amount of material needed while also opening up class time to include the active learning strategies so necessary in engineering. Demetry (2010) reinforced this view by maintaining that content-crammed courses have been a perennial barrier to more widespread adoption of pedagogies of engagement in engineering education.

Clearly, the approach of cramming CRS into already content-heavy class time does not embrace the potential for CRS to improve student engagement and student learning. The use of CRS should be planned as an integral component of the course (Beatty et al. 2006b) which enhances and reinforces the learning outcomes. The effectiveness of CRS depends strongly on the quality and variety of the questions, the design of the activities to encourage students to engage with the questions, and most importantly, allowing sufficient time for students to read, comprehend, discuss and work through the questions at their own pace, as well as allowing enough time for them to submit their answers in a stress-free environment. Trying to *add* the use of a CRS alongside traditional lecture class material, rather than *augment* the use of the CRS, will not demonstrate the true benefits of using CRS to students and will generally also not improve student learning.

This study trialled the introduction of a new, state-of-the-art CRS (Top Hat Monocle) in a third year engineering Fluid Mechanics course (n=45) to improve student engagement, motivation and cognition. The course was completely redesigned and restructured to address and alleviate content-cramming issues (Dunn et al, 2012; Toto and Nguyen, 2009; Demetry, 2010). It was recognised that for the potential benefits of CRS to be fully realised, more time must be allocated for student engagement and the active learning components of the course. In order to allow sufficient time to fully engage with the CRS and other classroom activities, traditional lectures were revised and the classroom lecture was *flipped* (Carberry & Amresh, 2012; Demetry, 2010). This paper presents the initial case study results.

1.1 Flipping Classes for Quality Instruction

Flipping allows an instructor to provide traditional, low cognitive level, lecture materials in an alternative format outside the classroom, freeing up class time normally used to 'convey' information to students (Toto & Nguyen, 2009). Instruction that used to occur in class was then accessed in advance of class (generally at home), so that students were well prepared and could derive the most benefit from time spent in the face-to-face learning environment (Tucker, 2012). Students worked through specially developed, narrated lecture material online each week using our learning management system (LMS), prior to attending the face-to-face class sessions. Face-to-face sessions were then used to foster student engagement by working through typical problems, providing feedback, introducing advanced concepts, and facilitating student discussions and other collaborative learning activities (Toto & Nguyen, 2009; Tucker, 2012). Toto and Nguyen (2009) maintain that flipping lectures retains the best qualities of the traditional teacher-centred lecture model while also including the best qualities of the active learning or student-centred teaching model.

In order to avoid confusion, the weekly narrated flipped lectures were renamed *hand-e-lectures* to reflect the convenience and flexibility these online lectures offered students. The time slot allocated for the original lecture was renamed the *workshop*. The students could work through and study the hand-e-lecture material when and where they wanted, and for as long as they wanted. Different students learn at different rates and this arrangement allowed them to spend as much time on the material as the needed. All students need time to be able to absorb and process the information needed before it can be applied (Toto & Nguyen, 2009). In order to encourage students to utilise and engage with the hand-e-lectures, a number of graded CRS questions were included as part of the online hand-e-lecture content. In order to answer the weekly online hand-e-lecture questions, students were first required to register as students on the Top Hat Monocle (THM) website (https://www.tophatmonocle.com/).

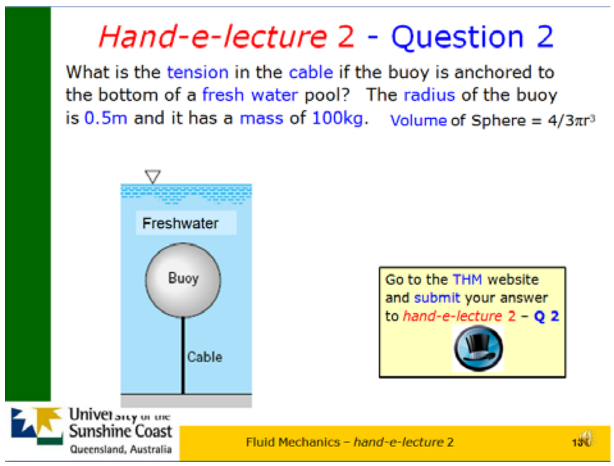

Figure 1: Typical *hand-e-lecture* CRS Question

Typically, each hand-e-lecture would contain between four and six CRS questions based on the weekly lecture material (Figure 1). Students were required to solve and submit answers to the CRS questions before attending the workshop session. Students could submit their answers to the CRS questions online, using a PC, laptop or Smartphone, or by SMS if these were not available. Reports showing the range of student responses to the hand-e-lecture questions were generated before each workshop and these were used to provide feedback and to identify any problem areas. Figure 2 shows a typical report from a numerical answer-type question. The numbers listed down the left hand side of Figure 2 show the various student responses to that particular question. The percentages listed down the right hand side of Figure 2 represent the percentage of students that submitted that response. The numbers in the horizontal report bars show the actual number of students that submitted that particular answer. The correct answer (200) is highlighted yellow in Figure 2.

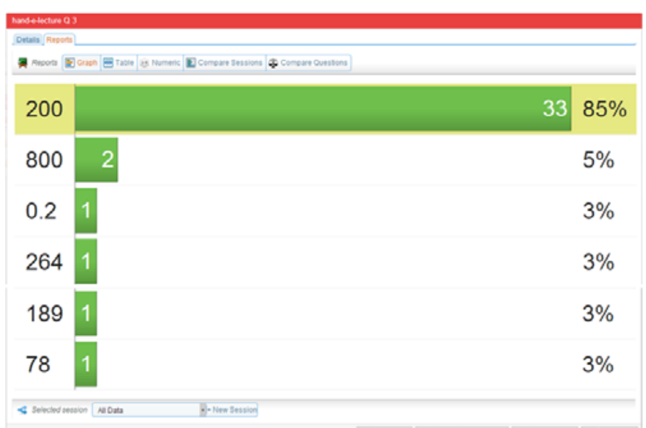

Figure 2: Typical *hand-e-lecture* CRS Question Report (correct answer highlighted yellow)

Workshops extended the hand-e-lecture content by including a variety of carefully designed, engaging activities (many were group activities) that used CRS questions to facilitate discussions, problem solving and case study analysis to enhance student cognition. Students used their mobile devices (phones, tablets, laptops) to respond to the CRS questions posed during the workshops. This arrangement also provided opportunities to identify potential problem areas, and to enable on-going assessment and evaluation of learning outcomes. To encourage participation in the workshops, students were also graded on their participation in the CRS process and on the correctness of their responses to the questions. A maximum of 15% of the students' total grade was allocated for participation in the hand-e-lecture and workshops using the CRS.

One of the many pedagogical benefits of the instant feedback provided by the CRS in the workshops was that it allowed students to evaluate their own performance and to monitor their own understanding of the workshop content (Dunn et al, 2012). This has been shown to result in a significant increase in students' long-term retention of knowledge (Kaleta and Joosten, 2007: Crossgrove & Curran, 2008). A further pedagogical benefit of receiving instant feedback on the students' responses was that the instructor could immediately identify areas that students were having difficulties with, or conversely, areas where the students were having no problems understanding. This allowed the instructor to adjust their instruction to provide further explanation on any problem areas, or to move on to the next topic with confidence that the students have understood. The flexibility that the instant CRS feedback gave the instructor in the workshops was particularly valuable. Traditional lectures are usually 'passive' in nature and it is very difficult to tell whether students are actually learning (Toto & Nguyen, 2009).

A further benefit of using the new CRS to ask students to answer summative questions posed in the hand-e-lectures and workshops was that the instructor could tell at a glance how students were doing overall. The new CRS trialled in this study provided instant EXCEL score sheets for all questions at the click of a button. This was very valuable information as it allowed the instructor to identify any individual students that were struggling. The instructor could then intervene and spend more time one-on-one with the students to provide extra instruction before the students became frustrated or gave up (Ash, 2012). The instant score sheets also allowed the instructor to identify areas of general misunderstanding within the class and provide extra explanation where required. An added benefit of this was that the students quickly realised that the instructor was very aware of how much effort the students were, or were not, putting into their learning.

2 Evaluation

A range of evaluation methods were used to gauge the effectiveness of the new teaching format in achieving increased student engagement, including classroom observation, student surveys using THM, feedback from student emails, and analysis of attendance and assessment results.

A significant increase in the levels of student engagement was observed during the new workshops compared to previous years' classes. Students actively participated in the workshops using their mobile devices. There was always much interaction and discussion among the students whenever a new THM question was posed. This was generally accompanied by a significant change in noise level within the classroom. It was interesting to observe how the noise level changed after each new question was posed as it generally followed a similar, cyclic trend, namely:

- The noise level would rise substantially as soon as the question was posed as students discussed the question amongst themselves;
- The noise level would gradually reduce over the next minute or so, as the students started working on their questions individually;
- The noise level would then reduce to nearly zero when the students were deeply engaged with their solutions;
- The noise level would then slowly start to rise again as more students submitted their answers on THM and discussed their answers with others.

From the instructor's point of view, this cyclic trend in noise levels was a very useful gauge of the appropriate time to move on to the next topic or question.

The CRS was also used to survey students on their perceptions of using the new technology and to gain a deeper understanding of how its use could be improved. At various times during the course, a number of evaluation questions were posed for evaluation purposes. The CRS was also used to obtain information on technical issues, such as which internet browser or phone provider the students were using or how they found the registration process and similar logistical queries. Figure 3 shows the results of one survey question: *"Do you like or do you not like being able to participate in the Workshops using THM?"* This question was asked in the second week of the new course at the end of the second workshop. Table 1 shows a number of other evaluation questions that were asked and the student responses.

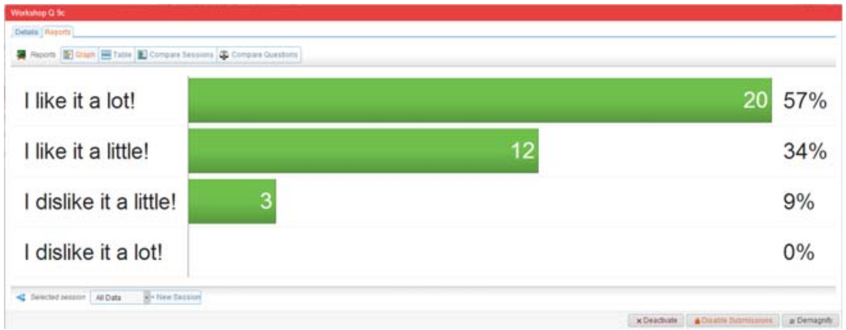

Figure 3: Report of One of the THM Evaluation Questions

Figure 3 and Table 1 show that between 86% and 97% of student responses to the evaluation questions relating to the use of the new CRS (THM), and the new flipped learning approach were positive. This was very encouraging, particularly as most of the students had never used a CRS before and this evaluation was undertaken only two weeks after they had first been introduced to THM. However, a small number of the students surveyed did say that they didn't like it much. Another benefit of the reporting system is that it is very easy for the instructor to see which students are responding to the questions. As it turned out, it was generally the same students that answered in the negative for all of the CRS evaluation questions posed that day. These students also got most of their answers to the workshop questions wrong. Perhaps they were just having a bad day? Overall, the student feedback on all of the evaluation questions was generally very positive. They were very supportive (responses 97% positive) of receiving instant feedback on their responses in particular. This reinforces previous research findings that CRS promotes greater student engagement and higher levels of motivation (Tucker, 2012; Blasco-Arcas et al., 2013; Bartsch, & Murphy, 2011; Toto & Nguyen, 2009; Demetry, 2010; Bakrania, 2012).

Table 1: Evaluation Questions and Student Responses

Evaluation Question	Possible Responses	Responses	% of Total
Do you like or do you not like being able to participate in the *Workshops* using THM?	I like it a lot!	20	57
	I like it a little!	12	34
	I dislike it a little!	3	9
	I dislike it a lot!	0	0
Do you like or do you not like being able to work through the material whenever it suits you?	I like it a lot	26	63
	I like it a little	10	24
	I dislike it a little	5	12
	I dislike it a lot	0	0
Do you think that working through the *hand-e-lectures* before the Workshop makes it easier to or harder to understand the Workshop material?	Much easier	19	50
	A little easier	14	37
	A little harder	5	13
	Much harder	0	0
Do you like or do you not like the way THM gives you instant feedback on the class answers?	I like it a lot!	30	83
	I like it a little!	5	14
	I dislike it a little!	1	3
	I dislike it a lot!	0	0
Do you think that the new *hand-e-lecture* and Workshop format will or will not help you to better understand the course material?	It will help a lot!	19	51
	It will help a little!	13	35
	It will not help much!	3	8
	It will not help at all!	2	5

The CRS was also used to collect feedback on technical and logistical issues associated with the use of the system. As this was the first time that this system had been trialled anywhere in Australia, another of the study aims was to investigate different students' experiences of interacting with THM using different Australian internet and mobile telephone service providers. In addition, the students' views on, and experiences with the registration process was of interest in this study. One of the first week's hand-e-lecture questions asked: *"How did you find the registration process through the Top Hat Monocle website?"* The results are shown in Figure 4.

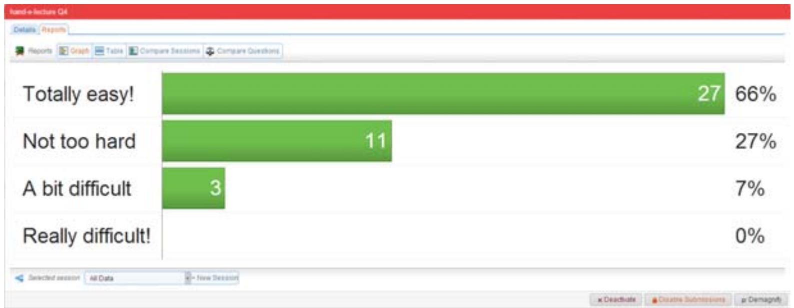

Figure 4: Report of Evaluation Question on Registration Experience

As shown in Figure 4, 93% of students (*n*=41) found the registration process easy. This is a very good result considering that this question was asked in the very first week of semester and most students had never used any type of CRS beforehand.

In addition to the formal evaluation that was conducted on the new teaching format, students were also asked to provide informal feedback by way of email on their perceptions of the new teaching format. While this invitation did not generate a large number of responses, the feedback that it did generate was generally very positive and supportive of the new teaching format. Two examples of this student feedback on the new teaching format are shown below:

- *"One of my favourite things is that we are exposed to, and tested on our understanding of new material at our own pace. This enables me (us) to bang our heads against something we find a bit curly until we have at least some understanding of it (or failing that narrows it down to 1 or 2 points that are easily cleared up in the 'workshop'). So when we are exposed to it in the workshop it's nothing new and we can focus on its applications and broader implications."*
- *"Between the HeL [that is, the* hand-e-lectures]*, the THM questions and the TuT questions I am engaged, and importantly not swamped, by material to keep it on my mind and to 'hold', if you will, the learning. That way the workshops are more like a spit and polish of the rough knowledge from the HeL and the TuT questions are the double check."*

2.1 Summary

A number of inter-related issues are contained in this paper that were difficult to tease apart. Separating the advantages of using a CRS in general, using THM in particular, the way in which the instructor used THM, and the overall teaching quality of the instructor is very difficult. The data gathered and discussed in this paper regarding THM are inextricably linked to the manner in which THM was used.

Regardless of the teaching methodology used, it seems logical to expect that the skill and enthusiasm of the instructor would play a significant role in student learning. To try to quantify this, Manteufel & Karimi (2010) investigated the effects that different instructors' teaching styles had on students learning the same engineering statics material. They found that students tend to achieve consistent grades commensurate with their effort, irrespective of the instructors' skills or efforts. Students who have the goal of achieving the highest possible grades often do so, while other students appear content to simply pass the class. Therefore, it could be reasonably expected that any new teaching format or tool that improves student learning, such as flipped lectures and CRS, will be beneficial to all students in the class. However, further research is required to fully investigate this.

The acceptance of CRS has been relatively slow in Australian universities (Dunn et al., 2012) despite their documented advantages and their large uptake in the USA. This may be due to the perceived problems with using these systems and a general reluctance to trial anything that relies so heavily on technology. A series of issues and recommendations related to the use of CRS, most of which arise when using traditional clicker devices, have been identified in the literature (Dunn et al., 2012). For example, the registration of the clicker devices should be streamlined (Barnett, 2006), and student training to use the devices should be prepared and delivered at the start of each semester (Caldwell, 2007). Students also often forget to bring their traditional clickers devices to lectures.

The technical problems associated with using mobile-phone-based CRS are quite different to the technical problems of using other CRS (Dunn et al., 2012). In this study, the typical problems associated with traditional CRS were found not to be an issue when using the Top Hat Monocle CRS. The pedagogical and technical challenges of using THM in this study were minimized because students were not using specialized hardware, but rather they were using their familiar mobile phones or laptops. This meant that no training was necessary. In addition, students were less likely to forget their mobile phones than a dedicated clicker device.

The new flipped lecture and CRS teaching format demonstrated a substantial increase in the level of student engagement, motivation and attendance compared to previous cohorts (Toto & Nguyen, 2009; Demetry, 2010; Bakrania, 2012). However, the increased levels of engagement did not appear to reflect on any large increase in students' individual grades in comparison to previous cohorts, although at the time of writing, the final grades were not yet complied. There are also many variables that could influence the results from one student cohort to the next and these would have to be taken into account to enable a realistic comparison. This was the first time that this new teaching method has been trialled and the inconclusive nature of the results could be attributed to the preliminary nature of this case study. The study in ongoing and it is expected that as more data becomes available, this will allow a comprehensive analysis to be undertaken on the pedagogical benefits of this new teaching format.

Overall, use of the new flipped lecture and CRS teaching format demonstrated a substantial increase in the level of student engagement, motivation and attendance compared to previous cohorts. Students were generally very supportive of the new teaching format and many asked whether the new format could be introduced into their other courses. The overwhelmingly positive responses to the Top Hat Monocle CRS were very encouraging.

3 Conclusion

This case study explores the use of a new, low-cost, state-of-the-art CRS which allows students to use their mobile devices (phones, tablets, laptops) to respond to a variety of numerical, multiple-choice, short-answer and open-ended discussion questions. In order to allow sufficient time to fully engage with the CRS and other classroom activities, traditional lectures were revised and the classroom lecture was *flipped*. Students worked through specially developed lecture material online each week prior to attending the face-to-face class sessions. Face-to-face sessions were then used to foster student engagement by working through typical problems using the CRS, providing feedback, introducing advanced concepts, and facilitating student discussions and other collaborative learning activities.

Overall, the new flipped lecture and CRS teaching format demonstrated a substantial increase in the level of student engagement, motivation and attendance compared to previous cohorts. Generally, students' perception of the effectiveness of using the new teaching format was overwhelmingly positive. The study in ongoing and it is expected that as more data becomes available, this will allow a more comprehensive analysis to be undertaken on the pedagogical benefits of this new teaching approach.

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