In-Class and Asynchronous Student Response Systems: A Comparison of Student Participation and Perceived Effectiveness

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CONTEXT: Student response systems (SRSs) are effective tools to enhance interactive learning in large lecture settings by making learning interesting and engaging with the use of a technology students are familiar with (Preszler et al., 2007). Furthermore, in-class SRSs provide instant feedback to students on their learning, reducing the need for teachers to engage outside of class (Walvoord and Anderson, 1998). However, learning happens in many forms and occurs as a result of students engaging in activities inside and outside the classroom (Astin, 1993; Pascarella and Terenzini, 1991). This study explores the effectiveness of learning activities using SRSs to enhance non-engineering student engagement and to support their learning in an engineering module of a general education course. To our knowledge, this is the first time that a comparative study on the effectiveness of in-class versus asynchronous SRSs based on student participation and their perceived effectiveness has been conducted.

PURPOSE: We hypothesise that SRSs can enhance student engagement and learning in engineering classrooms to better enable non-engineering students to learn about engineering concepts in a general education first year course on sustainability.

APPROACH: Quizzes, consisting of seven questions each and based on the assigned reading and learning material covered in the previous class, were administered in every engineering class through Google Forms (synchronous activities). In addition, online practice questions were created in our learning management system, Canvas, so that students were able to participate anytime from anywhere (asynchronous activities). At the mid-point of the course, a summative student evaluation about the effectiveness of the SRSs was conducted using an online questionnaire in Qualtrics. The survey explored the student perception on enhanced engagement and improved learning outcomes in an engineering module of a general education first-year course (N = 110) which included five other modules.

RESULTS: Forty eight out of 110 students (44%) completed the questionnaire to measure the effectiveness of the SRS. About three-quarters of the students strongly agreed and agreed that SRSs were helpful for their learning, increased their engagement with the course and would recommend extending the use of similar SRSs to other course modules, not just the engineering one. Overall, 75% of the respondents also believed that SRS increased their interest in engineering and improved their learning in this module of the course. Students expressed a preference for SRS tools embedded in Canvas over the use of Google Forms.

CONCLUSIONS: The results demonstrate the effectiveness of SRSs in enhancing non-engineering students' learning experience by improving their engagement in an engineering classroom. What is clearly evident from the student perception is that the use of SRSs, both in-class and asynchronous, is highly recommended for courses that require students to engage in a significant amount of assigned readings that is beyond students' main area of study and in cohorts with wide-ranging academic backgrounds as was the case for this general education course.

KEYWORDS: Student response systems, asynchronous, online quizzes, active classroom

Context

Teaching engineering concepts to a general education audience at undergraduate level is especially challenging as the student cohort is essentially non-engineering focused. The current study was conducted in a first year general education course at the University of Auckland. The purpose of this course is to introduce students to the theory, science, and practice of sustainability. The complex and dynamic nature of sustainability is illustrated in this course through a multi-disciplinary approach, addressing the roles and implications of social and cultural practices (sociology module), legal framework (law module), current governance, economic and business models (business module), planning, design and management of the built environment (planning module), basic science that underpins sustainability (science module), and product and technology manufacturing and life cycles (engineering module).

Typical class sizes for this general education course range from 100-150 students. This course is team-taught whereby lecturers from various disciplines (Engineering, Arts, Business, Law, Science, and Planning) contribute to the course in their respective modules. The engineering module comprises four weeks of lectures and tutorials (three weeks before and one week after the mid-semester break) while the other five Faculties split the remaining 8 weeks of the course into their discipline-specific modules. Last year (2016) was the first time the lead author taught this course, and while experiencing some positive feedback at the time, there was a considerable room for improvement as was evident through student feedback received, either through students' comments or through student course evaluations. In addition, many students didn't read the assigned course materials uploaded through the learning management system (LMS), Canvas.

The goal of this study was to improve student engagement and evoke interest in an engineering module on sustainability in a general education course comprising mainly non-engineering students. It was hoped to improve engagement not just in the classroom but also online through the implementation of student response systems (SRSs) to foster active learning.

Introduction

To be an effective teacher in engineering seems challenging to many academics as there seems to be a disconnect between 'getting through content' and 'ideals of teaching'. This presents significant challenges when incorporating active learning to reduce the transmission style of lecturing. Constructivism taken too far can dilute the rigour needed in STEM subjects (Felder, 2012). By contrast, rigour taken too far can be stifling and disengaging. Hence, there is a need to rethink traditional engineering pedagogical practices to help students learn in an exciting environment without compromising on the rigour that is necessary for the engineering education.

One of the conventional methods for engaging students in the classroom has been through textbooks and external readings. Course instructors assign readings to students for a variety of reasons, most commonly because it is often impossible to present all recommended course material during class time (Ryan, 2006). Completion of assigned readings before a topic is covered in class allows students to better comprehend the class material, and in turn, increases in-class participation and student interactions (Ryan, 2006; Gurung, 2003; Narloch et al., 2006; Appleton et al., 2006).

However, student compliance with reading assignments has steadily declined over time (Clump et al., 2004; Sappington et al., 2002; Burchfield and Sappington, 2000). There can be a variety of reasons for this decline, including increased presence of electronic gadgets and the distractions they can create in students' academic lives (Gilbert and Fister, 2011). Nathan (2005) links low levels of reading comprehension to a student's desire for more personal time. A National Endowment for the Arts report (2007) reinforces the hypothesis that students spend significantly more time on media and electronic devices than on reading (Hoeft, 2012). Rather than banning these gadgets and technology from the classroom it is worth exploring whether these can be used for the benefit of student learning instead.

New techniques to increase student reading and class participation for a better understanding of the assigned course material are constantly trialled (Gibbs and Jenkins, 1992; Novak et al., 1999). One such technique is assessing students learning through frequent quizzes on reading assignments (Narloch et al., 2006; Angus and Watson, 2009). Having regular in-class quizzes can encourage students to pay closer attention to the assigned reading material as well as the course content, which can improve their understanding not only of the reading material, but also of the lecture material presented in class (Narloch et al., 2006; Brothen and Wambach, 2001; Graham, 1999) resulting in increased student engagement as defined by Axelson and Flick (2011). In addition, frequent quizzes may lead students to study regularly during the semester rather than cramming just before the final exam (Narloch et al., 2006; Clump et al., 2004; Gilbert and Fister, 2011).

However, it is reported that although scheduled or surprise in-class quizzes can motivate students to complete the assigned reading, students tend to view such quizzes as punishment depending on how those are administered (Sappington et al., 2002; Graham, 1999). Hence, it is important to administer quizzes optimally and integrate with other learning activities for a holistic course design rather than quizzes being an add-on and met with resistance by students.

A variety of ways to administer online quizzes (in-class and asynchronous) exist and different methods may vary in effectiveness. For example, the use of randomly administered quizzes may result in higher levels of reading compliance (Ruscio, 2001), and selection of subsets of questions from large question banks can reduce the likelihood that students will simply memorize response options without learning the material (Daniel and Broida, 2004).

Furthermore, research suggests that presenting feedback separately, after the student answers each question, including both information about accuracy and a source of additional information, can enhance the learning experience for students (Ryan, 2006; Brothen and Wambach, 2004). Pedagogical research findings also suggest that online in-class quizzes for assigned readings can provide students with a variety of positive learning outcomes (Hillman, 2012; Salas-Morera et al, 2012). For example, the use of online administered quizzes has been shown to motivate students to complete assigned readings, increase participation in class discussion, and improve performance on exams for material covered both on the quizzes and in class (Brothen and Wambach, 2004; Johnson and Kiviniemi, 2009).

The question ‘do regular online assessments enhance student-learning outcomes?’ is still the subject of considerable debate in the literature. Bonham et al. (2003) and Engelbrecht and Harding (2004) noted that online assessments (as compared to manually marked paper-based assessments) resulted in no discernable difference in student performances over a range of summative assessments. Likewise, Smith (2007) found that online quiz scores showed higher correlation with final examination marks than laboratory or assignment marks. Grimstad and Grabe (2004) found that students who completed voluntary quizzes significantly improved their exam performances. However, their conclusions were explained by good students being both motivated to take voluntary quizzes and likely to do well on examinations. Brothen and Wambach (2001) cautioned that mandatory quizzes only improve exam performance if students employ an efficient strategy of using the quizzes to test their own knowledge of the material, rather than attempting to use the quiz to learn the material.

Kibble’s (2007) study of a large cohort (n ~ 350) of Medical Physiology course demonstrated the effect of varying the incentives given to students to complete online quizzes. Kibble summarised results under three key findings: first, students who elected to use online quizzes performed better in summative examinations; second, when the incentives were increased, student participation rose dramatically; and third, quiz scores were significantly correlated with final examination results. Similarly, Angus and Watson (2009) found support for the hypothesis that regular usage of online learning tools significantly and positively contributed to student performance.

Overall, much of the literature suggests an improvement in learning outcomes when online quizzes were used as low-mark formative (or summative) assessment involving medium to large cohorts (greater than 100 students). However, more data and studies will be valuable in this domain. The lack of research with respect to the use of frequent formative assessments for engineering classrooms comprising mainly non-engineering students provides the opportunity to fill that research gap. No single research project can possibly examine all facets of this complex relationship between learning interventions and student learning, but the focus can be on developing a greater understanding of one element without denying the existence of the others (Fry et al. 2009, Kahu, 2013). Therefore, the focus of this study is to explore the student perception on the use of frequent formative assessment through the use of online quizzes in the classroom, i.e. learning together (synchronous), and outside the classroom (asynchronous).

One method of administering effective online formative assessments is through the use of in-class SRSs (Preszler et al., 2007). An SRS is a form of technology that offers teachers the opportunity to ask students in the classroom multiple-choice questions to which they reply individually by selecting an answer. This was traditionally conducted through a hand-held wireless transmitter, called 'Clickers'. Students choose their answers by using Clickers that send a signal to a receiver attached to the teacher's computer, and the results are displayed for the entire class to see. However, Clickers are usually expensive to obtain for large classes. With the advent of new digital technologies, their use is also becoming obsolete.

Moreover, digital, mobile technologies are increasingly making their way into the classroom such as SRSs that use Google forms or online polling or quiz software (Mathiasen, 2015). Mathiasen (2015) states that SRSs play an important role in assessing student progress and capturing the type of learner data that allows teachers to understand their students' progress and intervene in a timely manner, often feedback can be immediate after students completed the task. It makes learning interesting, and engages students with a technology they are familiar with in an interactive learning format (Preszler et al., 2007). Based on the literature (Padhye, 2016), not only the feedback on the accuracy of student selected answers but providing sources of additional information can enhance the student learning.

Objective

This study aims to design, apply, and evaluate effective online quizzes as a part of SRSs to enhance student learning in a general education course that teaches engineering concepts to mainly non-engineering students.

Methodology

The SRSs were implemented as two components. Five in-class quizzes (in Canvas) were administered for every engineering class after the first week of lectures. These quizzes consisted of six multiple choice questions each, plus a discussion-oriented question for which there was no correct answer. The open-ended question, based on the overall theme of the lecture, was used to record student responses and generate in-class student discussion regarding the topic. Since participation in such in-class SRS relies on student attendance and the intention was to reach all students enrolled in the course, an asynchronous component to the SRS was also offered whereby new online quizzes were created so students could participate in this activity anytime from anywhere. Literature shows that providing such flexibility in administering quizzes is essential to increasing student participation and engagement (Sappington et al., 2002; Graham, 1999). Both SRSs, asynchronous and synchronous, were trialled as voluntary student self-assessments and were therefore not marked as part of the overall grade. The student perception on the effectiveness of the SRSs for their learning was collected via an online questionnaire comprising eight questions.

In-Class Online Quizzes (synchronous)

The design of in-class online quizzes was informed by the literature and by formative assessment models (McSweeney & Weiss, 2003; Smith, 2007; Stillson & Alsup, 2003). The quizzes were written with the third-party software, Google Forms. Google Forms were selected based on their versatility, availability, and student familiarity (Gehringer, 2010; Haddad and Kalaani, 2014). Many universities are using Google Apps for Education. Google forms can serve as an effective tool for SRSs, providing a wide range of response formats that extends beyond traditional clicker options. Students are provided with instant feedback for their answers, immediately after each quiz, and are given credit for the number of questions they answer, or the number of correct answers they submit over the course of the engineering module. Previous work has shown that giving credits increases the response rate for online quizzes (Gehringer, 2010) even though these quizzes are not part of the course assessments.

Overall, five in-class quizzes were administered during five engineering classes. All quizzes comprised seven questions each. Students were advised before the class started to bring in an electronic device, capable of accessing the internet. Links for the quizzes in Google Forms were displayed during class for students to access. Ten minutes were dedicated in each of five classes for students to complete the quizzes and for in-class discussion of upcoming questions relevant to the topic.

Online Quizzes in Canvas (asynchronous)

In parallel with in-class SRS, online quizzes were created in Canvas as an asynchronous SRS. A total of 31 multiple choice questions that were different from in-class quiz questions were created based on the lecture content and assigned reading material of the engineering module. The link for students to access those were posted each week on the course webpage and remained active for the entire time of the engineering module before the semester break when it was closed. The purpose of creating another form of SRS was two-fold: first, to capture students who do not attend classes and thus missed participating in synchronous SRSs, and second, to compare students' preference of one form of the SRS over the other.

Questionnaire

After the six weeks of the course, which included three weeks of the engineering module and the other three weeks of science and sociology, a summative evaluation for measuring the effectiveness of the SRSs was conducted using an online questionnaire in Qualtrics during the seventh week of the course. This study received approval from our university's Human Participants Ethics Committee (reference 018673). Student consent was obtained as part of the online questionnaire in order to collect student responses on their perception of the effectiveness of the SRSs.

The questionnaire included eight questions about student engagement and improved learning outcomes in the engineering module of the course. The first question asked students about their major field of study while questions 2-7 required answers on a 5-point Likert Scale (strongly agree to strongly disagree). Question 8 was an open-ended question which encouraged students to submit their comments through text input.

Intended Benefits

The key benefits of both synchronous and asynchronous quizzes for learning include more detailed and frequent feedback to support student learning. This is possible through in-built analysis of results available during in-class and asynchronous SRSs. Online quizzes will help students study regularly and gain understanding of the course material throughout the semester rather than simply cramming before a comprehensive exam in order to improve their performance. Students are also expected to engage more actively in the class as a result of understanding concepts covered in assigned readings. SRSs are also expected to promote discussion and collaboration among students during class and provide a safe space for shy and unsure students to participate actively. Overall, we expected that students will face fewer difficulties in learning some of the advanced engineering concepts covered in the class as a result of better understanding of fundamentals through additional readings.

The key benefit to teachers include more consistent, efficient, and effective feedback mechanisms to inform course design, identification of learning thresholds, and optimise content delivery. Understanding the strategies and tactics of SRSs and formative assessment will provide insights into learning design with the aim to improving engineering course materials and contingent teaching techniques as previously described by Mathiasen (2015) and van de Pol et al. (2009), respectively. With the implementation of SRSs it is hoped to correctly diagnose students' understanding of in-class as well outside classroom teaching to be able to provide targeted support. For example, teachers can revise learning activities to target specific aspects of learning misconceptions revealed by the SRSs which are particularly useful for students before exams.

The learning success of incorporating effective SRS can be measured via a number of proxies, for example, through:

1. Participation statistics of the SRSs (scores, knowledge misconceptions, number of attempts etc.),
2. Summative evaluation (questionnaire responses),
3. University student evaluation results, and
4. Personal feedback obtained from students, either verbally or through written communication with the teacher.

Results and Discussion

The mean response rate for five in-class quizzes was 76% which correlated well with the average student attendance during the engineering module ranging from 75 to 85 students per lecture. However, the mean response rate for asynchronous quizzes was 90%, indicative of an increased activity outside class time reaching more students which is consistent with findings from the literature (Sappington et al., 2002; Graham, 1999). Students scored on average slightly over 70% for both, in-class and asynchronous SRSs. It showed that students' performance was not affected significantly based on the mode of SRS delivery, whether synchronous during class time or asynchronous.

Forty eight out of 110 students (44%) completed the questionnaire in Qualtrics, based on questions that explored students' perceptions on the effectiveness of SRSs used in the engineering module of the general education course. Figure 1 summarises students' responses to this questionnaire. About three-quarters of the students (73%) strongly agreed and agreed that SRSs were helpful for their learning, increased their engagement with the course and would recommend extending the use of similar SRSs to other course modules, not just the engineering one. Overall, 75% of the respondents also believed that SRS increased their interest in engineering and improved their learning in this subject area of the course.

Based on the responses, it was also evident that the choice of the SRS tool used is important as there was a difference in the preference for tools embedded in Canvas: students tended to prefer quizzes embedded in Canvas (average Likert score was 4.1) compared to quizzes designed in Google Forms (average Likert score was 3.7). One of the possible reasons for explaining this difference could be that students make more use of asynchronous SRS due to the flexibility of time and place (Sappington et al., 2002). Another possible reason could be the familiarity of students with Canvas as it is our university's LMS for all courses.

For the open-ended question requesting comments and suggestions from students, 13 respondents commented. The overall feedback regarding the implementation of SRSs in the engineering module of the course was favourable. Seven of the respondents specifically addressed the SRSs and its positive impact on their learning and particularly for exam preparation which is evidenced in the student comments below:

"…the SRS is useful and easy for me to practice what I have learnt in class by answering those online quizzes."

"Extremely helpful when studying for the exam, provided a rough scope of what to study and let you know what to focus on."

Other students could also see the benefit of extending the use of SRSs to other modules of the course indicating an overall desire to have active learning opportunities across the entire course, not just the engineering module. The following student comment illustrates the benefit of implementing SRSs on learning as perceived by the student:

"I understand that the SRS was only available for the engineering module and this definitely helped my understanding of the content and was useful for the test in revision and practice. For other sections of this course that did not use SRS I definitely did not understand the content as well or do as well in the test as there were no practice quizzes ….whereas I learnt from the answers that were provided at the end of each quiz for the engineering section."

Summative evaluations (SET) that are used university-wide at the end of each course and semester are another source for assessing the effectiveness of teaching methods and the effectiveness of changes to course design. Despite the fact that the end of semester report is typically generated for the entire course, individual teacher evaluations reflect student perceptions on teaching methods implemented in particular modules.

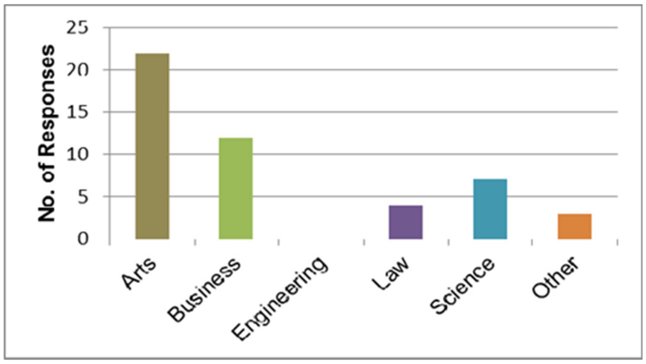
According to the SET report for this course, 78% students were satisfied with the quality of the course, and more importantly, 89% believed that the engineering module was taught effectively (mean score was at 4.3 on a 1 to 5 Likert scale from strongly agree to strongly disagree) due to the implementation of SRSs. Similar to student responses from the questionnaire administered only in the engineering module, comments included in the SET report centred on the effectiveness of practice quizzes and multiple choice questions for optimal learning. For example, one student commented:

"…[the teacher] had variety of content and was engaging in class. I enjoyed how his content asked for perspective, and how the two options were presented, it wasn't so much a case this is right and this wrong. More a case of there are the two options and here are the conditions of both. The revision MCQs were also very helpful."

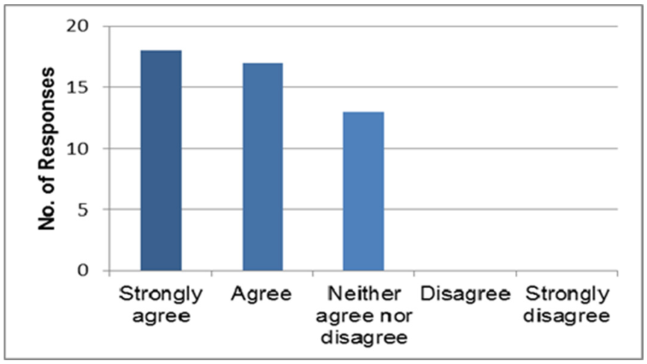
Apart from these documented questionnaires and usage data from the SRSs, verbal and visual feedback is a key element in assessing effectiveness of implemented measures. During the duration of the course, the teacher was approached on several occasions by students, either face-to-face or through email, to express their satisfaction with SRSs, whether used in-class or asynchronous providing practice questions.

In addition to increased attendance, the class interaction level was found to be higher compared to the previous year as students participated actively in discussions on the class topics. Students also appeared better prepared for each lecture and most of them did not struggle with the background material which was fundamental for most of the advanced engineering concepts covered in class. However, further investigations are required to assess students participating in SRSs are more likely to complete the required readings in the context of general engineering education courses where the majority of students will not major in the discipline.

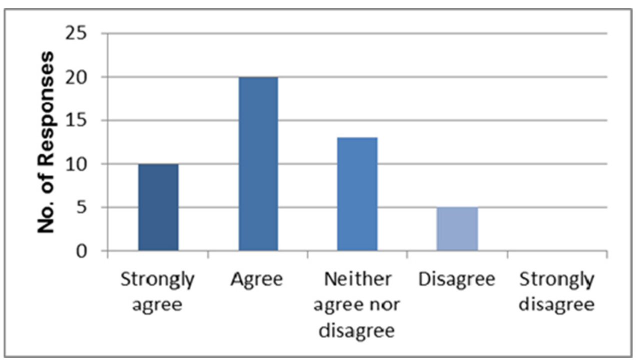
1. **Following is my subject area:**



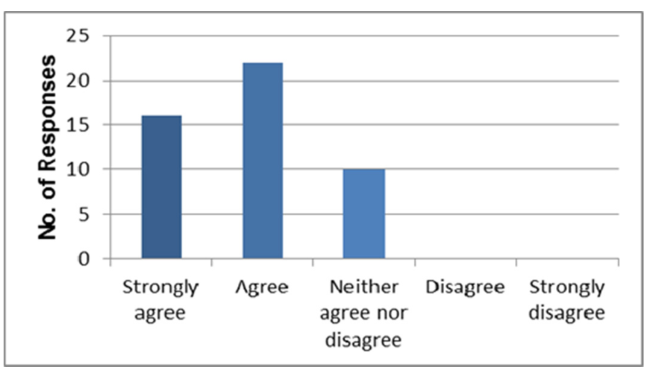
2. **Student Response Systems used in the Classroom were helpful to my learning of the course material.**



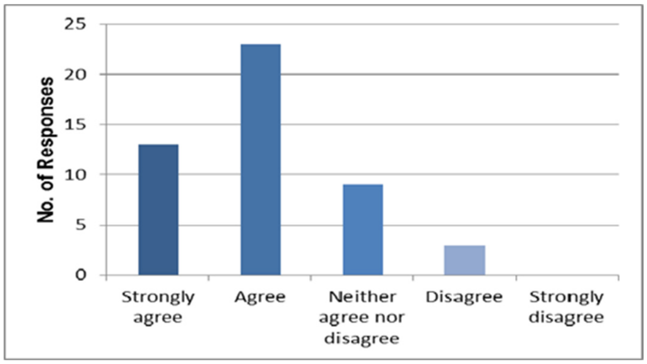
3. **I enjoyed participating in Student Response Systems more through Google Forms (in- class practice quizzes).**



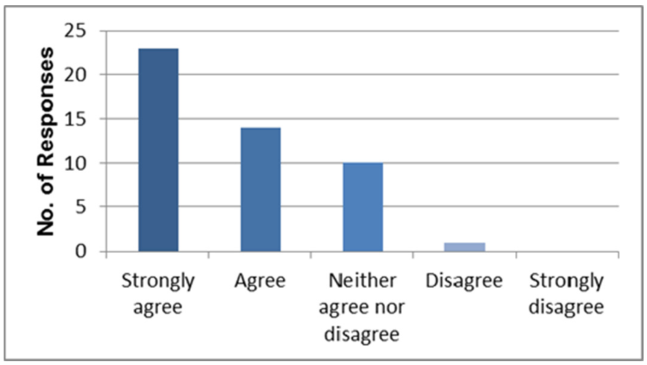
4. **I enjoyed participating in Student Response Systems more through Canvas (practice questions) outside the classroom.**



5. **Student Response Systems increased my engagement in the course.**



6. **I would recommend adding Student Response Systems to other courses as well.**



7. **Overall, Student Response Systems increased my interest in the course and made me better learn the course content.**

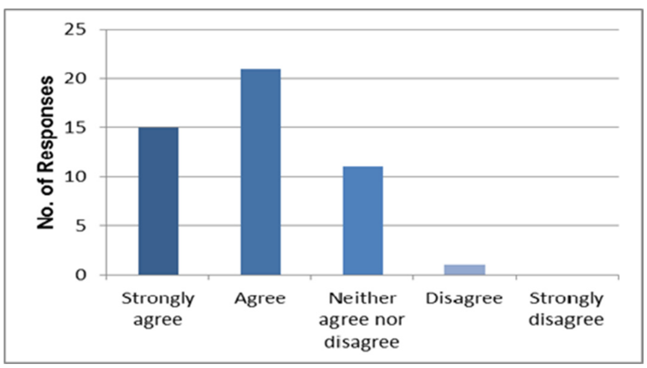


Figure 1: Student responses to questionnaire items for measuring the effectiveness of the SRS

Conclusions

The goal of the study was to include teaching activities in the course design to foster student engagement and provide more scaffolded learning opportunities about engineering concepts targeted at a diverse audience where engineering is not the main area of study. We found that asynchronous quizzes had a greater rate of participation compared to the ones conducted (online) in class. The results demonstrate effectiveness of SRSs in enhancing student learning and engagement in a general education course that teaches engineering concepts to mainly non- engineering students.

Our findings of online administered SRSs as successful tools for enhancing student learning are consistent with similar findings in other fields (Cassady et al, 2001; Dinov et al, 2008; Henly, 2003; O'Dwyer et al, 2007). Therefore, the use of SRSs is highly recommended for any instructor teaching a course that requires students to engage in a significant amount of assigned readings that is beyond students' main area of study and in cohorts with wide-ranging academic interests.

From our experience, it is advisable to provide both synchronous and asynchronous learning opportunities to maximise student engagement. Moreover, it would be interesting to investigate the effects of 'written quizzes' versus 'online quizzes' on student engagement and learning outcomes. However, reduced costs, increased efficiency of analysis, and ease of setting up SRS make online administration much more appealing compared to the collection of responses on paper, particularly in large class settings. In addition, the truly formative nature of SRSs by providing students with the opportunity of multiple attempts at solving a problem and immediate feedback not just for students but also teachers can only be attained in the online format. It should be noted that online quizzes are just one of the many tools available for SRSs but are one of the most effective due to some of the advantages mentioned above.

In summary, students' responses to the question 'Overall, Student Response Systems increased my interest in the course and made me better learn the course content' support the observation that SRSs effectively implemented using online tools can enhance student learning and engagement in the classroom. While this exact question has not apparently been posed in the literature, variants on the same theme have been and the results from this study are found to be in agreement with this notion (Kibble, 2007; Angus and Watson, 2009).

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