A Smartphone-based Student Response System for Obtaining High Quality Real-time Feedback – Evaluated in an Engineering Mathematics Classroom

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The many pedagogical benefits and educational uses of student response systems (SRS) are well documented (Caldwell, 2007). These include improved student learning, increased student interaction and increased student satisfaction, to list but a few. However, while several different types of SRS exist, they currently have limited input capabilities. Most devices do not allow for a generic freeform input, such as mathematical equations, graphical methods or circuit diagrams. This lack of freeform input is of key concern in the Engineering, Science and Mathematics disciplines where such information is fundamental to the student learning experience. For example, consider the minimisation of a Boolean function using a Karnaugh Map or the design of an electrical circuit to meet a predefined requirement or a mathematical analysis of a problem. It is important that students can carry out these fundamental processes and, if we are to capture immediate feedback of the students' grasp of such methodology, then it is necessary for a SRS to facilitate freeform input. In this paper we evaluate a system that uses student-owned smart phones and tablets, along with the appropriate applications, as a 'smart device' student response system (McLoone *et al*, 2013). This system allows for freeform response and also offers a more practical and portable solution in comparison with existing solutions. In brief, the system consists of three key components, namely a student application that allows for freeform input (through sketching capabilities), a lecturer 'review and feedback' application and a cloudbased service for co-ordinating between these two applications. This paper presents a brief overview of the smart phone-based SRS and evaluates its potential benefits in a classroom context, namely a first year Engineering Mathematics class in DCU. Initial feedback from both the lecturer and the students is very positive. Details of the actual Mathematics module, the evaluation process and the feedback obtained are presented within.

INTRODUCTION

Student response systems exist in the educational literature under many different guises (Fies and Marshall, 2006), including audience response systems (Miller *et al*, 2003), classroom response systems (Roschelle *et al*, 2004), voting machines (Reay *et al*, 2005) and clickers (Barber and Njus, 2007). These systems are all very similar in nature, consisting of a transmitter device for the students to communicate their responses, a receiver device for the lecturer to collate this information and software that presents the responses in a convenient form. The research literature clearly illustrates the many pedagogical benefits of student response systems including improved student learning, increased student interaction, increased student preparation for classes, increased student attendance, increased student satisfaction and the creation of an enjoyable learning atmosphere (Barber and Njus, 2007; Caldwell, 2007; Moredich and Moore, 2007; Auras and Bix, 2007; Skiba, 2006). In addition, SRSs can be used for student assessment (Caldwell, 2007) and for obtaining anonymous student feedback (Graham *et al*, 2007).

Unfortunately, most of these devices only allow for a multiple-choice input, whereby students select from a set of possible answers to a given question. Some devices do allow for a numerical or texual- based submission. However, none of these devices cater for a more generic freeform input, such as a mathematical equation, a circuit diagram or a graphical method. This lack of freeform input is of key concern in the Engineering and Science disciplines where such information is fundamental to the student learning experience. Consider, for example, the scenario whereby a student is required to carry out a mathematical analysis of a problem. While it is nice to get the correct answer, it is ultimately the process of analysis itself that provides the real insight to the student learning. It is very important that students can carry out such analytical processes and, if we are to obtain real-time feedback of the students' grasp of such knowledge, then is necessary for a SRS to facilitate freeform input.

McLoone *et al* (2013) have developed such a system for use on smart phones and/or tablets. The system consists of a student application that allows for freeform input (through sketching capabilities), a lecturer 'review and feedback' application and a cloud-based service for coordinating between these two applications. Figure 1 below gives an overview of the overall system and illustrates how it can be used.

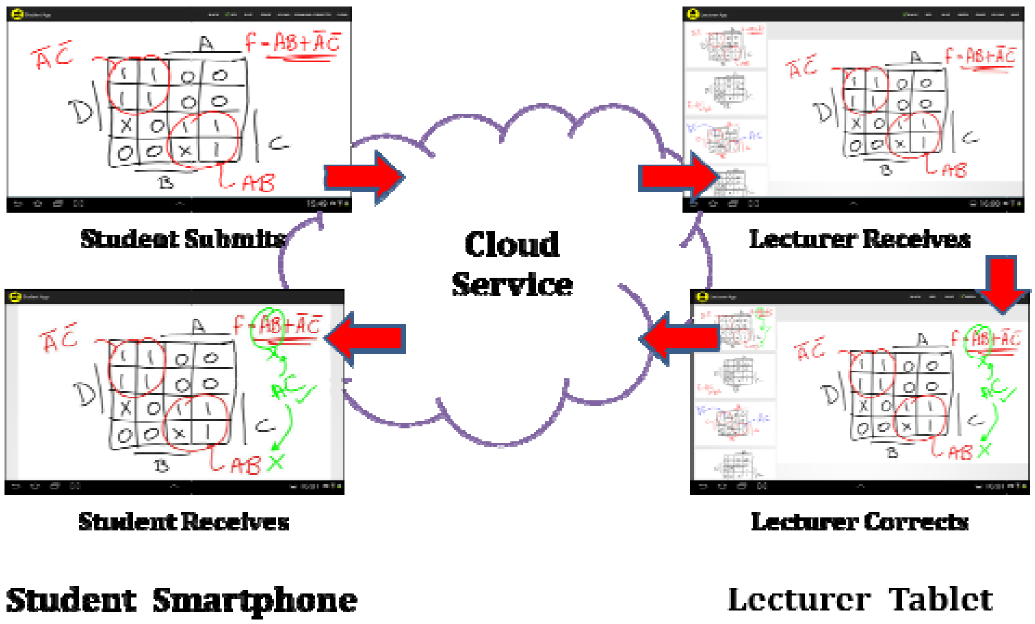

Figure 1: The Smartphone

Using the student application on their smartphone (or tablet) the student can sketch an answer to a posed question. This response can then be submitted anonymously in real-time to a shared database, which is currently stored on the Google App Engine cloud service. The lecturer can view all received anonymous responses (again, in real-time) and can select any of those responses for further analysis. The lecturer can also add edits to any of the responses and send this back to the students, if need be. It is this system that is evaluated in this paper. Currently, the system is only available for Android based smartphones and tablets.

The rest of the paper is structured as follows. The next section outlines the methodology used for evaluating the smartphone-based SRS. An overview of the educational situation is also provided. Results of the evaluation are presented and analysed in section 3. The paper ends with some conclusions and suggestions for future work.

METHODOLOGY & EDUCATIONAL SITUATION

The smartphone-based SRS was evaluated in a first year Engineering Mathematics module in DCU. This 5 ECTS module is taken by all first year engineering students in DCU including students taking Electronic, Digital Media, Mechatronic, Information and Communications, Mechanical and Manufacturing and Biomedical Engineering. The module takes place in the second semester of first year and is the second mathematics module taken by these students. It has two key sections. The first six weeks of the module covers basic calculus (differentiation, integration, applications of integration and differentiation and an introduction to ordinary differential equations) while the second six weeks covers complex numbers and matrices. The SRS was evaluated during the first 6 weeks of the module.

There were 167 students registered for the module but attendance was relatively poor due to the availability of online notes and, in some instances, recorded lectures. Thus, the typical class size in attendance was approximately 70 students and comprised of about 10 female and 60 male students. Furthermore, there were 15 international and 3 mature students in attendance, on average.

The lecturer of the module (and co-author of this paper) has found that students tend to have a prescriptive understanding of topics in functions and calculus, i.e. they have a fixed rule-based knowledge which allows them to process certain problems in a structured fashion provided that they are similar to ones encountered before. It is therefore a challenge to augment this rote-learning with a more flexible ability to visualize and understand the key concepts. The purpose of using the SRS was to see whether the technology could be effective in gauging the students' ability in this regard. Hence, questions posed were simple and required little or no computation or manipulation of expressions but instead challenged the students' fundamental understanding. An additional aim was to investigate how effective it would be in maintaining students' interest during a two-hour lecture on Friday mornings.

Several questions were given to the students during the evaluation. An example of one such question involved assessing the students' understanding of the absolute value operation. Students were sent a depiction of the function $f(x) = \sin x$. They were then asked to add two more functions to this sketch to graphically represent $g(x) = |\sin x|$ and $h(x) = \sin |x|$. A sample set of student responses, as received on the lecturer's tablet is shown in figure 2, with one such response selected by the lecturer for post analysis and discussion.

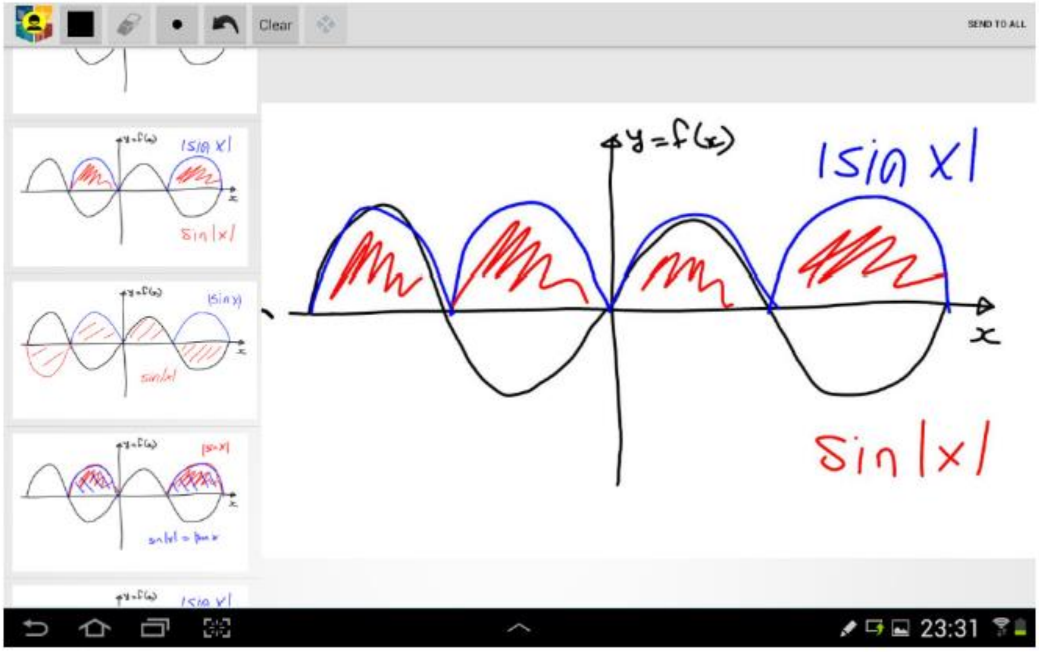

Figure 2: Sample sketch responses for the functions *g(x) = |sin x|* and *h(x) = sin |x|*

Some students tend to assume that any function with an absolute value as part of it must produce positive output. This was evident in several of the responses received from the students. This question clearly challenges this particular misconception. On receipt of the student responses, the lecturer now has the opportunity of highlighting this misconception and can draw the students' attention to the issue at hand.

Several such questions were posed during a typical lecture session on two different occasions. At the end of the second occasion, students were presented with a survey seeking their feedback on the new smartphone-based SRS. The lecturer, who had no prior knowledge or experience of the SRS, was also asked for his feedback. Both the lecturer's and the students' feedback are presented and discussed in the next section.

RESULTS AND ANALYSIS

A quick poll indicated that about 40% to 50% of the attending class of students had access to Android based smartphones or tablets. Students who did not have a suitable device were teamed up with someone who did and so the exercises were all group-based. In total, 46 survey forms were completed and returned to the lecturer at the end of the evaluation sessions. The student feedback is summarised in table 1 below.

Table 1: Student feedback on smartphone-based SRS, where 1 to 5 represents strongly disagree, disagree, not sure, agree and strongly agree respectively.

Statement	Average rating (1-5)	Std. dev.
I found the app easy to use.	4.15	0.70
I felt the app was quick and responsive.	3.15	1.23
The app performed as expected.	3.33	1.03
The app provided a good way to interact in class.	4.35	0.79
The app provided a good way to give feedback/responses.	4.22	0.92
The flexibility of providing a sketch is really useful (in comparison to choosing either a, b, c or d for example).	4.22	0.99
The use of the response system makes my learning more enjoyable.	4.50	0.55
I was motivated to respond to the lecturer's questions using this system.	4.30	0.76
I would like to use this response system again.	4.30	0.76

Table 1 clearly shows that most students were strongly in favour of the smartphone based student response system and, in particular, felt that the flexibility of providing a sketch as an input option was really useful. Moreover, they felt that the system provided a good means of interacting in class. They were motivated to respond to the lecturer's questions and wanted to use the system in future classes. The feedback in table 1 also shows that there was a mixed feeling regarding the student application itself with a large number of students noting that the application was not quick and responsive and did not work as they expected. This issue was largely due to some inherent bugs in the current system, which is still very much a work in progress. These caused the application to crash or stop working quite often and proved quite frustrating, at times, to some of the students. Nevertheless, they still appreciated the value of the overall system.

From the additional feedback obtained, via comment boxes, several students noted that the SRS was a positive way of "*interacting between student and lecturer*." They "*liked the freedom of drawing*" their "*own answer*" and found the graphical input useful and felt that it allowed the lecturer to see if they really understood the material. As expected, most students appreciated the "*fact that all submissions were anonymous*" allowing them to provide responses without the fear of being identified and it also meant that they were "*less worried about the answer being wrong.*" Finally, most students commented on how the system crashed quite often and would like to see this issue resolved for future use.

The lecturer of the module was extremely positive in his assessment of the technology, although it was not without its problems, as previously noted. Despite this, the lecturer noted that the sessions were keenly enjoyed by the class who responded very well to the different class-room dynamic and it certainly served its purpose of breaking up an otherwise passive 2-hour slot. The lecturer also indicated that he would like to use it more widely in his future lecturing.

In the opinion of the lecturer the technology highlights to students the central importance of a visual understanding of mathematics and the system's simple input capabilities, which at first may seem a drawback, actually became a positive in this regard. For example consider the case of sketching a function. The simple drawing scheme available means that students are forced away from their traditional approach of computing several input-output pairs and interpolating between them. Instead they must perform a simple free-hand sketch based on their intuitive understanding of the function's behaviour. The lecturer stresses to them that it is this intuitive understanding of a function's general behaviour that constitutes real mathematical knowledge, as opposed to manipulation of tabulated data. While students are resistant to this approach, allowing them to practice in a relaxed classroom atmosphere is one step towards developing this skill.

The lecturer also noted that, like any new learning technology, it is important to choose questions that are simple and clearly assess a small number of principles. Vaguely worded or overly complex scenarios do not translate well to this arena. In addition, it is important to encourage students to submit blank or empty solutions if they genuinely don't know the answer (given that the purpose of the exercise is to gauge the level of understanding of the class as a whole).

The majority of students engaged well and the sessions proved very worthwhile. However the anonymity provided by the SRS did produce a certain amount of obscene replies on one occasion when the lecturer had the system hooked up to the inclass screen, while replies were coming in. Although these can be brushed off and can actually serve to break tension and build rapport they can sometimes become intrusive and get out of hand. It is important to develop a smooth system for connecting the device to the projector and disconnecting as appropriate, something that came with experience of how the process flowed. The lecturer noted that the development of a simple software solution that could simplify this process, i.e. allowing responses to be hidden until desired, would be extremely beneficial. Interestingly, several of the students proposed similar suggestions in their feedback.

CONCLUSIONS

This paper has evaluated a recently developed smartphone-based student response system (McLoone *et al*, 2013) in a first year Engineering Mathematics class in DCU. Both the lecturer and the students found the concept of offering freeform input using sketches very beneficial for submitting and receiving real-time in-class responses that, in turn, provided valuable insight to the students' deep understanding of the mathematical content covered during the lecture. In addition, the system provided a good means of interaction within the classroom and helped break up what was otherwise a 2 hour long traditionally one-way lecture. The students, in particular, noted that the anonymity provided by the system allowed them to respond without fear of being identified and, therefore, of giving a wrong answer. On the other hand, the lecturer and, indeed, some of the students noted that such anonymity also resulted in some obscene submissions being received by the lecturer. This issue could potentially be resolved by not allowing students to see such submissions. In other words, the system can be used so that only the lecturer can view all student responses and, subsequently, can choose to share whichever response they seem suitable for further discussion. Moreover, the authors feel that this issue arises as a result of a slight immaturity among first year students entering college (and particularly among male students). It is hoped that this issue will be investigated in future evaluations of the SRS.

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