Use and Evaluation of a Smart Device Student Response System in an Undergraduate Mathematics Classroom

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Abstract

This paper outlines the use and evaluation of a recently developed smart device student response system (SDSRS) in an undergraduate engineering mathematics classroom.The unique SDSRS allows for a more flexible input than existing response systems, such as clickers, and thus offers students a mechanism for sketching graphs, writing equations and annotating figures. Such information content is particularly relevant in mathematical-based modules, where the methodology is often more important than the answer itself. The SDSRS also allows the lecturer to instantly capture this real-time information from the students and, hence, obtain quick and valuable insight to the students' comprehension and use of the taught material. In turn, the lecturer can provide the students with immediate and arguably more useful feedback to address any apparent deficiencies in knowledge that may have arisen.

The SDSRS was used in a first year Engineering Mathematics module in the School of Electronic Engineering, Dublin City University (DCU) to evaluate its potential usefulness to both the lecturer and the students. This paper outlines the evaluation study carried out and presents detailed feedback from both the lecturer and the students involved. It is worth noting that neither party had seen or used the SDSRS previously. Overall, highly positive feedback was obtained, as is summarised within.

Keywords: Classroom Response Systems, Student Response Systems, Classroom Interaction, Undergraduate Mathematics

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1. Introduction

As teachers, we are all too familiar with the blank faces and lack of responses that we get from students when asking if they have any questions about material that we have just covered in class. This is particularly true in larger classes where students are even more likely to refrain from asking or answering questions in the open classroom in fear of embarrassing themselves should they say something meaningless or give an incorrect answer. The advent of classroom technology and in particular that of student response systems (Roschelle et al., 2004, Fies & Marshall, 2006, Bruff, 2009, Blasco-Arcas et al., 2013) have helped address this issue to a large degree.

Student response systems (SRSs) such as clickers have increased in popularity over the last two decades and the literature contains many examples of their use in the classroom across a wide range of disciplines including engineering (van Dijk et al., 2001), astronomy (Duncan, 2006), psychology (Morling et al., 2008), business (Heaslip et al., 2014), nursing (Meedzan & Fisher, 2009), chemistry (MacArthur & Jones, 2008) and many others. Response systems exist in the educational literature under many different guises (Fies & Marshall, 2006), including audience response systems (Miller et al., 2003), classroom response systems (Roschelle et al., 2004), voting machines (Reay et al., 2005), student response systems (Blood & Neel, 2008), personal response units (Barnett, 2006), classroom communication systems (Beatty, 2004), clicker assessment and feedback technology (Han & Finkelstein, 2013) and clickers (Barber & Njus, 2007, Lantz, 2010). All such systems consist 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 abundance of available research literature clearly illustrates the many pedagogical benefits of student response systems. These include improved student learning, improved motivation, increased student interaction, increased student preparation for classes, increased student attendance, increased student satisfaction and the creation of an enjoyable learning atmosphere (Barber & Njus, 2007; Caldwell, 2007; Moredich & Moore, 2007; Auras & Bix, 2007; Skiba, 2006). In addition, SRSs can be used for student assessment (Caldwell, 2007), for aiding active learning (Sarason & Banbury, 2004) and for providing a more flexible means of implementing classroom assessment techniques, commonly referred to as CATs (Angelo & Cross, 1993). Most notably, such systems offer students anonymity when submitting their responses, leading to increased participation within the classroom as students who would otherwise be afraid of publicly giving the wrong answer are now more likely to engage (Graham et al., 2007).

However these response systems suffer from limited input capabilities. Most systems typically offer a multiple-choice style input where students are required to select one of a possible set of answers. In some instances, a numerical or textual-based input is also available. Unfortunately, these systems do not cater for a more generic freeform style input that would allow students to write equations, sketch diagrams or annotate figures. This lack of flexible input is a major drawback in science, technology, engineering and mathematics (STEM) disciplines, where such information is central to the students' learning. For example, consider the scenario of a student carrying out the mathematical analysis of an arbitrary problem. While it is desirable to get the correct answer, it is ultimately the process of analysis itself that provides the real insight into 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' knowledge of these processes, then is necessary for a student response system to facilitate freeform input.

McLoone et al. (2015a, 2015b) have recently developed such a system, which they refer to as the smart device student response system (SDSRS). This system works on smart phones and/or tablets and 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 co-ordinating between these two applications. This system alleviates the aforementioned issues associated with existing SRS solutions. In this paper, we evaluate the use of this new system in an Engineering Mathematics classroom to explore its potential benefits to both lectures and to students.

In the next section, we briefly present and outline the key aspects of the novel SDSRS. In section 3, we outline the evaluation study and the educational context in which it was carried out. In section 4 we provide the analysis and feedback obtained from the study. Both lecturer and student feedback are obtained. It is worth emphasising that neither party had seen or used the SDSRS prior to the evaluation study. The paper ends with some key conclusions from the evaluation study.

2. The Smart Device Student Response System (SDSRS)

The reader is referred to McLoone et al. (2015a, 2015b) for a detailed overview of the proposed SDSRS system. Here, we simply provide a brief overview of the main features of the system for the convenience of the reader. The system consists of three key components, namely a student application, a lecturer application and a cloud-based service for co-ordinating information between these applications.

Figure 1 – Smart device student response system – (a) student sketch application with sample sketch and (b) lecturer application showing sample images in either a grid view or a two-panel, editing view

The student application offers basic sketching functionality, allowing students to draw, erase and edit sketches as appropriate. Students use their fingers (or a stylus if available) to interact with the touch screen on their device. An example of a student sketch is shown in Figure 1(a) and clearly illustrates the input flexibility offered by the new SDSRS in comparison with existing solutions such as clickers.

The lecturer application provides the same sketch capabilities as the student application in order to allow for a lecturer to edit or mark up student responses. More significantly, it allows for the viewing of multiple images in a quick and convenient manner, as in Figure 1(b). An available template option allows the lecturer to prepare sketches and questions in advance of the lecture and these can subsequently be sent to the students at the appropriate time.

The cloud-based service is the hidden component of the response system and is employed to co-ordinate all exchanges of information between the student and lecturer applications. Here, the Google App Engine is used to perform this service. The SDSRS is currently only available for Android-based tablets and smartphones.

In operational terms, students use their smartphones (or tablets) to sketch an answer to a given question. They submit their responses anonymously, in real-time, to a shared database currently stored on the Goggle App Engine cloud service. The lecturer can view all received anonymous responses in real-time on their tablet 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 class, if need be (for example, for students connected remotely to the classroom).

3. Classroom Evaluation & Educational Context

The SDSRS was evaluated in a first year Engineering Mathematics module in the School of Electronic Engineering, Dublin City University (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 SDSRS 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.

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

Several questions were given to the students during the evaluation, which was conducted during a typical lecture session on two different occasions. Three such example questions are summarised below.

Example Question 1 – *Given a sketch of the function $f(x) = \sin x$, add two more functions to this sketch to graphically represent $g(x) = |\sin x|$ and $h(x) = \sin |x|$.*

This question involves examining the students' comprehension of the absolute value operation. The lecturer has found that some students tend to assume that any function with an absolute value as part of it must therefore always produce a positive output by nature. This particular question is designed to challenge this notion.

Example Question 2 – *Given a sketch of the piecewise linear function f(x), shown in Figure 2, sketch its derivative.*

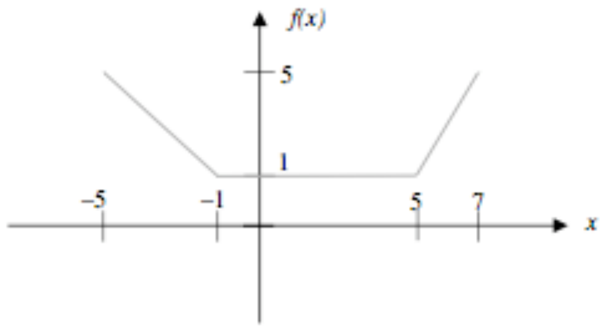

Figure 2: Piecewise linear function $f(x)$

The lecturer noted that most students tend to correctly compute the relevant slopes but do not correctly deal with the boundary points where there is a discontinuity in the slope (points $x = 5$ and $x = -1$ in this case). This question helps focus on this important aspect and affords an opportunity for in-class discussion on the concept of left and right hand limits.

Example Question 3 – *Given a sketch of the piecewise linear function f(x), shown in Figure 3, find a point b such that* $\int_a^b f(x)dx = 0$

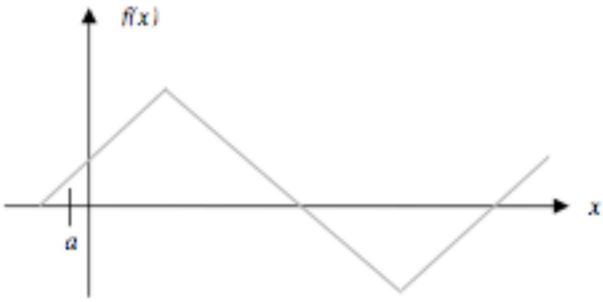

Figure 3: Piecewise linear function $f(x)$

This question gauges the students' understanding of the relationship between the definite integral of a function and the area between its curve and the x-axis. There are several correct solutions to this question, including the trivial case of $b = a$ (interestingly, most students do not obtain this solution), which, once again, affords ample opportunity for in-class discussion.

A sample set of student responses, as received on the lecturer's tablet is shown in Figures 4, 5 and 6 for each of the above respective example questions. In each figure, a sample response has been selected by the lecturer for post analysis and discussion. The responses obtained clearly reflect the issues that the lecturer had highlighted with many of the students making the mistakes that the lecturer had anticipated, based on previous experience.

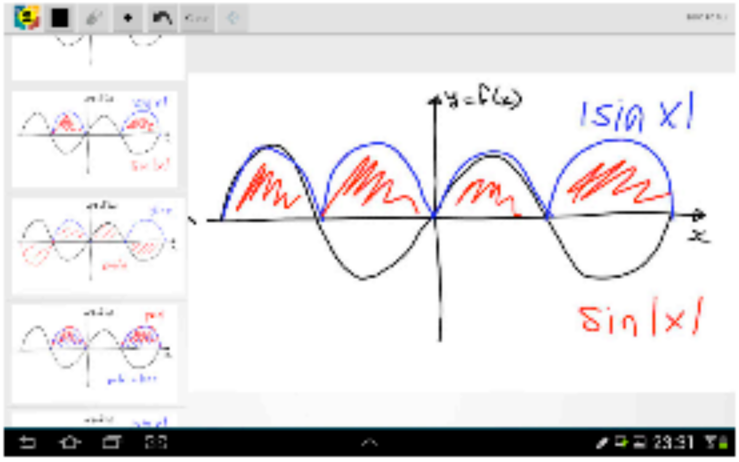

Figure 4: Sample student responses to example question 1

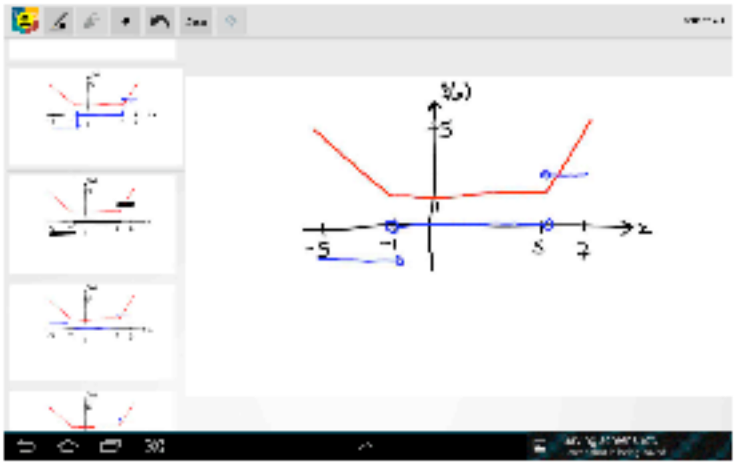

Figure 5: Sample student responses to example question 2

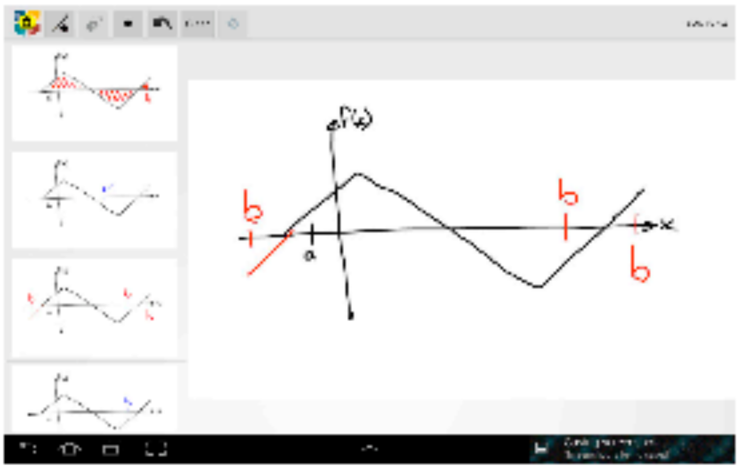

Figure 6: Sample student responses to example question 3

On receipt of the responses, the lecturer was able to take the opportunity to use the students' own responses to highlight the various misconceptions and to focus their attention on the issues at hand.

A quick poll indicated that about approximately 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 mostly group-based. At the end of the evaluation period, paper questionnaires were used to obtain student feedback on the use of the SDSRS. All responses were anonymous and participation was entirely voluntary.

The lecturer (and co-author of this paper), who had no prior knowledge or experience of this student response system, was also asked for his feedback on both the system and its potential benefits to the teaching of his module. Initially, the lecturer was simply requested to write down his thoughts and opinions on the SDSRS, without any external influence or interference. This information was then discussed, in person, with the lead author, to explore any interesting aspects or issues that may have arisen.

Both the lecturer's and the students' feedback are presented and discussed in the next section

4. Feedback and Analysis

4.1 Student Feedback

In total, 46 survey forms were completed and returned to the lecturer at the end of the evaluation sessions. Students were presented with a range of statements and requested to rate each one as either 1 for strongly disagree, 2 for disagree, 3 for not sure, 4 for agree or 5 for strongly agree. Table 1 shows the average and standard deviation of the ratings given by the students for each of the presented statements.

Table 1 clearly shows that most students were strongly in favour of the SDSRS 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 indicates that some students noted that the application was not as quick and responsive, and did not work, as they expected. This issue was largely due to some inherent bugs in the existing implementation of the SDSRS, which is still very much a work in progress. These caused the application to crash or stop working at times and proved somewhat frustrating to a few of the students. Despite these implementation issues, the students still appreciated the value of the overall system.

Students were also given the option of providing additional feedback via comment boxes. The responses obtained offered an arguably more useful insight to the use of the SDSRS. The key findings can be catergorised as followed:

Interaction – Several students noted that the SDSRS was a positive way of "*interacting between student and lecturer*." One student added that a key aspect of the system was its capability of allowing "*the whole class to interact with the lecturer*."

Graphical Input – Some students "*liked the freedom of drawing*" their "*own answer*" and found the graphical input useful. One student remarked that they felt that it allowed the lecturer to see if they really understood the material.

Anonymity – As expected, most students appreciated the "*fact that all submissions were anonymous*" allowing them to provide responses without the fear of being identified and, therefore embarrassed. It also meant that they were "*less worried about the answer being wrong.*"

Peer learning – It was very interesting to observe that quite a few students appreciated the fact t that they "*could see all*" the "*answers and see which were wrong and why.*"

Improvements – While students were made aware at the start that the SDSRS was currently only available for Android-based devices, a few still requested a version for use on iphones and ipads. Finally most students also commented on how the system crashed quite often and would like to see this issue resolved for future use.

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 – Student feedback (1 – 5 represents strongly disagree to strongly agree respectively)

While most of these comments were foreseeable at the outset of the evaluation study, it is nevertheless re-assuring to see that the students themselves appreciate the key benefits of the recognised by the students. However, the aspect of peer learning (Mazur, 1997) was perhaps the most interesting of all the comments received and is arguably an additional benefit of the SDSRS that has not been highlighted previously.

Since students can see all the answers from their colleagues, they have the benefit of real-time peer learning within the classroom. This is potentially a very powerful learning mechanism for the students involved. With standard response system such as clickers, students could see how they performed in the context of the class, i.e. were they the only one getting the answer incorrect/correct and, if not, how many others were getting the question incorrect/correct also?

With the SDSRS, students can now also see firsthand exactly how other students are actually approaching questions, what mistakes they are making and where they are making those mistakes. In essence, they can see how their colleagues are thinking about and approaching problems. This is hugely beneficial for students and in particular for those studying STEM modules, where problem solving forms an essential aspect of student learning.

4.2 Lecturer Feedback

The module lecturer 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 classroom dynamic and it certainly served its purpose of breaking up an otherwise passive Friday morning 2-hour slot. The lecturer also remarked that he would like to use it more widely in his future lecturing and, in doing so, would like to embed some examples in his notes that would cater for the effective use of the SDSRS.

The lecturer felt that the SDSRS emphasizes to students the central importance of a visual understanding of mathematics and the system's simple sketch input capabilities is perfectly suited for this purpose. 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. In the lecturer's opinion, it is this intuitive understanding of a function's general behaviour that constitutes real mathematical knowledge, as opposed to the procedural manipulation of tabulated data. While students are often resistant to this approach, the lecturer noted that allowing them to practice in a relaxed classroom atmosphere, using technology such as the SDSRS, is one step towards developing this important learning skill.

The lecturer found the SDSRS intuitive and easy to use but noted that, like any new learning technology, it is very important to choose questions that are simple and clearly assess a small number of principles. Poorly expressed, vaguely worded or overly complex scenarios do not translate well to this arena. Interestingly, he also felt that it is important to encourage students to submit blank solutions if they genuinely don't know the answer. This is particularly true if the purpose of the exercise is to gauge the level of understanding of the class as a whole, otherwise there is a possibility that the lecturer may obtain a somewhat skewed impression of the class' knowledge.

The lecturer found that the majority of his students engaged well and the sessions proved very worthwhile. However the anonymity provided by the SDSRS, while improving engagement, did result is some unwanted issues arising. The lecturer remarked that a certain amount of silly and obscene replies were obtained on one occasion when the system was hooked up to the in-class screen, while replies were being received in real-time. Although these can be brushed off and the silly replies 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.

5. Conclusions and Future Work

This paper has evaluated a recently developed smart device student response system (SDSRS) by McLoone et al. (2015a, 2015b) in a first year Engineering Mathematics class in DCU, to determine its potential benefits to both the lecturer and the students. Neither party had seen or used the SDSRS previous to this study.

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 and deep insight to the students' 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 two-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 embarrassed of giving a wrong answer. However, 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 can potentially be partially resolved by preventing students observing 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 responses they see fit for further discussion and analysis within the classroom.

Finally, feedback from the students also revealed an additional benefit of using the SDSRS, namely peer learning. This system provides a mechanism that allows students to see the responses from their colleagues and, hence, to see exactly how they approach and solve the same problems (and not just their answers). Therefore students can all potentially learn from each other as well as from the lecturer in real-time in the class room.

As part of future work, it is hoped to evaluate the SDSRS across other subject areas and, in particular, other STEM related disciplines. SDSRS.

As discussed in the Introduction, student response systems are known to improve interaction and to provide an increased number of student responses, largely due to the anonymity aspect. Both these benefits are clearly recognised by the students in the above comments. The key aspect and benefit of the SDSRS is its ability to allow for freeform input. This was also

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