A Novel Smart Device Student Response System For Supporting High Quality Active Learning In The Engineering And Science Disciplines*

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Abstract

This paper proposes and presents a unique smart device student response system (SDSRS) that allows for a more flexible input than existing classroom response systems, such as clickers. This, in turn, allows students to respond to the lecturer with higher quality and more relevant information and, thus, improves their active learning. This is of particular relevance in the science and engineering disciplines where methodology is as important, if not more so, than the final answer. The SDSRS allows the lecturer to quickly obtain this pertinent information in real-time within the classroom environment.

The proposed system consists of three main elements, namely a student sketch application, a lecturer view-and-edit application and a central cloud-based service to co-ordinate the exchange of information between the two applications. The system was evaluated within two different engineering classrooms, with very positive feedback obtained from both the lecturers and students involved. Details of the evaluation process, and the feedback obtained, are presented within.

Keywords: Classroom Response Systems, Student Response Systems, Smart Device Based Response Systems

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1. Introduction

Active learning involves incorporating learning activities into the traditional lecture to encourage students to do something other than simply listen passively to the lecturer (Bonwell & Sutherland, 1996, Faust & Paulson 1998, Exley, 2004). The benefits of active learning are well documented in the research literature and includes improved motivation, better retention of material, and developing thinking skills (Prince, 2004). In addition, it helps break up the potential monotony of a typically traditional one-way lecture.

The advent of classroom response systems (Roschelle, 2004, Fies and Marshall, 2006, Bruff, 2009, Blasco-Arcas et al., 2013) has aided and promoted the inclusion of active learning within the classroom as such technology provides a quick and easy means of real-time interaction within the classroom environment (Sarason & Banbury, 2004). The use of this technology makes it significantly easier and faster to collect real-time student responses, for a range of questions, in comparison with using a pen and paper approach, for example. In doing so, the lecturer is able to offer immediate feedback to the students regarding obvious errors and incorrect responses. Prompt feedback has been noted by Chickering and Gamson (1987) as one of the seven principles for good practice in undergraduate education.

A classroom response system (CRS) combines software and hardware that allows the lecturer to pose questions to students in real-time and to receive immediate feedback. Such systems typically 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 interprets the responses and presents them in a convenient and useful form. An example of one such system is presented in Figure 1 below.

Figure 1 – The iClicker classroom response system (*image from http://wiki.ubc.ca/images/0/08/Click*)

CRSs exist in various different forms, including voting machines (Reay et al., 2005), student response systems (Blood & Neel, 2008), audience response systems (Miller et al., 2003), clicker assessment and feedback technology (CAF) (Han and Finkelstein, 2013) and clickers (Barber & Njus, 2007, Lantz, 2010).

There is an abundance of available literature outlining the many uses of and pedagogical advantages offered by these response systems. As well as improving active learning, it has also been reported that CRSs can improve student motivation, improve student interaction within the classroom and provide a more flexible means of implementing classroom assessment techniques, commonly referred to as CATs (Angelo & Cross, 1993). It has also been shown that the use of CRSs can increase student attendance, increase student preparation for classes, and improve student satisfaction within the classroom (Caldwell, 2007, Aura and Bix, 2007, Moredich and Moore, 2007, Skiba, 2006, Heaslip et al., 2014). Most notably, these 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).

The CRS can also be used as a mechanism to provide formative feedback to students on previously taught material. Formative feedback (Shute, 2008) is effectively information given to the student with the key focus of improving their learning. Here, for example, a lecturer could use the CRS to determine how much knowledge students have pertaining to a topic that was covered in previous lecturers. This provides the students with some indication as to their own level of knowledge of the material covered while also allowing the lecturer to identify any gaps in the students' understanding that may need to be rectified before moving on to a new topic.

However, despite all these aforementioned benefits, existing CRSs, such as the recently prevalent clickers, have limited input capabilities. Such 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, clickers do not cater for a more generic freeform style input that would allow students to write equations, sketch diagrams, or highlight coding errors. This lack of flexible input is a major drawback in the Engineering and Science disciplines, where such information is central to the students' learning.

For example, in various engineering related modules, it is important that students can sketch basic circuits, graphically minimise digital logic functions and mathematically solve a range of problems. Similarly, in mathematics students need to be able to sketch polynomials, depict information on Venn Diagrams and show complex numbers on the Argand diagram. In Chemistry, it is important to be able to visually illustrate how various elements combine to form a range of compounds. In Physics, free body diagrams are an essential aspect of analysing the forces and moments acting on a given body. The list of such examples is endless, particularly in the disciplines of Science and Engineering.

In brief, the art of problem solving is as important, if not more so, then the actual solution itself. While clickers allow students to respond with a selection of possible answers, they reveal little or no insight to the actual problem solving ability of the student. In order to obtain this invaluable insight, it is necessary for the CRS to facilitate freeform input.

In the next section, we present and outline a novel student response system that alleviates the aforementioned issue. This new system makes use of smart devices (tablets and smart phones) and, along with the appropriate applications, enables students to respond using sketches. This system allows for more useful and relevant answers to be communicated between the students and the lecturer in real-time during the traditional lecture and, thus, facilitates a higher quality active learning experience. The smart device student response system (SDSRS) was evaluated by two different classes of engineering students. Details of the evaluation process and a summary of the key feedback obtained from both the students and lecturers involved are outlined in section 3. The paper concludes with some suggestions for future work in section 4.

2. The Smart Device Student Response System (SDSRS)

The proposed 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.

The student application offers basic sketching functionality, allowing the 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. The sketch options available to the students were intentionally limited to focus students on solving the problem in question rather than exploring the nice, but not always necessary, features that other similar sketch applications tend to offer. An example of a student sketch (in this case, a Venn diagram) is shown in Figure 2 and clearly illustrates the input flexibility offered by the new SDSRS in comparison with existing solutions such as clickers.

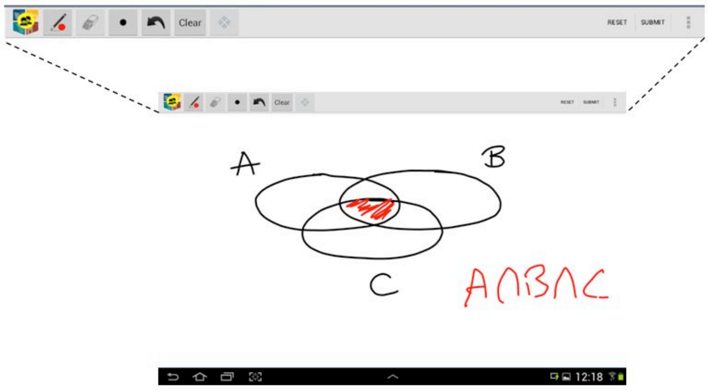

Figure 2 – A sample student sketch as viewed on the student application. The menu bar has been enlarged for ease of viewing.

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. Here, the lecturer can view the images in a scrollable grid format, as illustrated in Figure 3(a), or in a two-panel window, where the main panel contains a selected image while the side panel contains a scrollable list of all images, as shown in Figure 3(b).

Finally, 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. Currently, the SDSRS is only developed for Android-based tablets and smart phones. However, the cloud-based service is agnostic with regard to the smart device operating system and, therefore, suitable applications for non-Android devices, such as the iPad and iPhone, can easily be integrated into the existing system in the future.

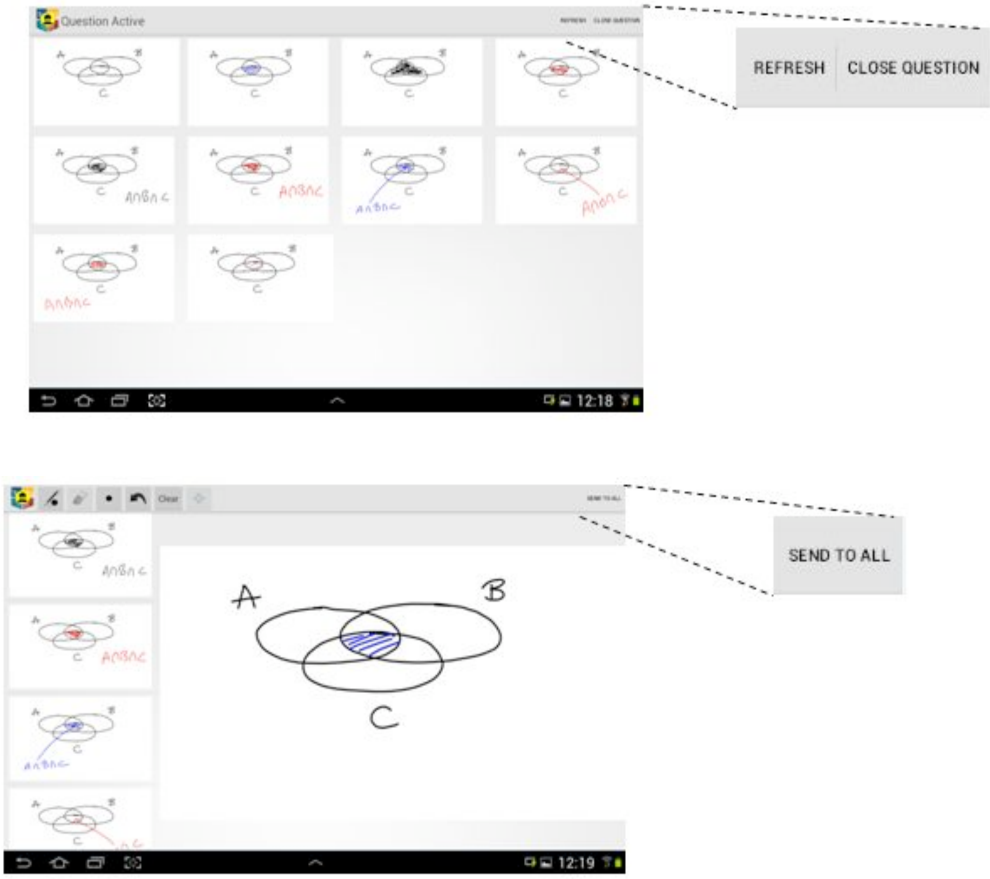

Figure 3 – The lecturer application showing sample images – (a) grid view and (b) two-panel, editing view. Part of the menu bar has been enlarged for ease of viewing.

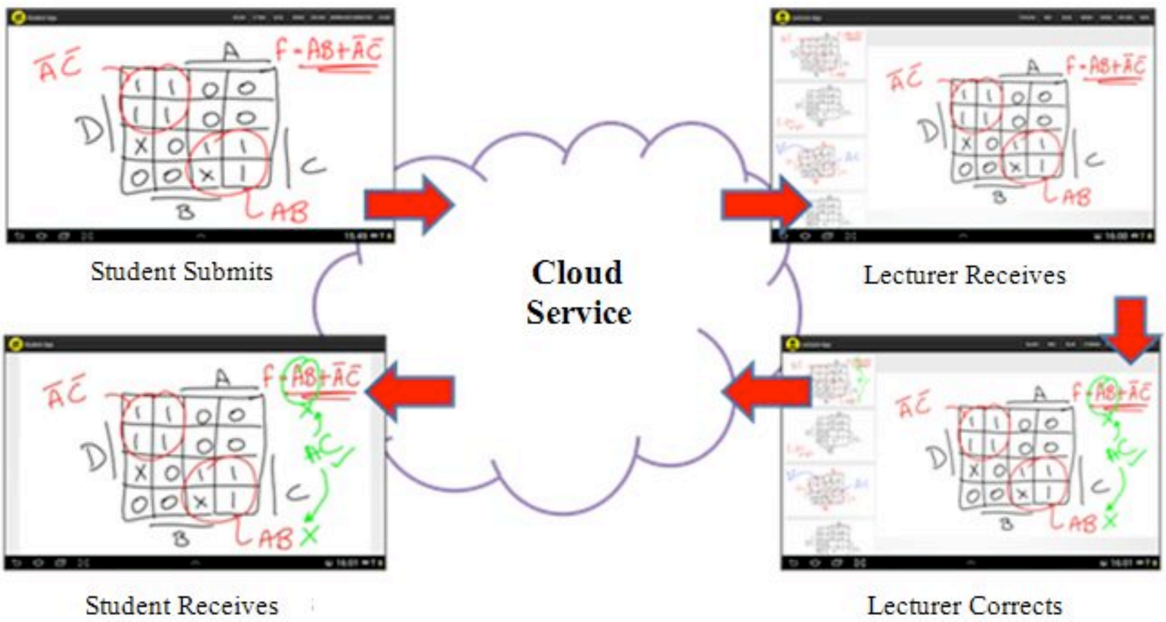

Figure 4 – An overview of the main operation of the proposed SDSRS

Figure 4 gives an overview of the overall response system and illustrates its principle operation. Using their smart phone or tablet, students respond in real-time, using appropriate sketches, to a question posed by the lecturer during class. These responses are submitted anonymously to a shared database, currently stored on the Google App Engine. The lecturer can view all student submissions, once again in real-time, and can select any number of these for further analysis and discussion. The lecturer also has the option of editing received responses and can return an edited response to the students. In the latter instance, the returned response is received by the whole class, on their individual devices.

3. Classroom Evaluation & Feedback

The proposed smart SDSRS was evaluated by two different classes of Electronic Engineering students at the National University of Ireland Maynooth. The first group consisted of 13 students taking a Computing module in the first year of their degree programme. The class comprised 10 male and 3 female students. There was 1 mature student and 3 international students (for whom English is their second language) in this group. The students evaluated the smart device based system during one of their typical traditionally-taught lectures. Here, students were presented with a range of subject related questions, to which they were required to respond via the student application on their phones or tablets. A sample of one such question required the students to show the bitwise AND of the two 8-bit binary numbers 11000111 and 01110111. Typical student responses, as viewed on the lecturer's tablet, are given in Figure 5(a).

The other group was a second year class studying a module on System Dynamics and also consisted of 13 students, 9 male and 4 female. This class had 3 mature students and 2 international students (for whom English is their second language). Once again, the student response system was tested during a typical lecture slot. A sample question from this module required the students to illustrate the typical step response associated with two different damping values, 0.1 and 0.9 respectively. A typical set of student responses for this question is shown in Figure 5(b).

In both cases, the various questions were chosen to assess the material that was covered during the lecture slot. For example, in the case of the second year Systems Dynamics class, the lecturer first covered the material relating to how changing the damping factor affects a system's output response. On completion, students were then posed a series of questions, using the proposed SDSRS, in an effort to gauge how well they had grasped the material that had just been presented. In any instances where the majority of students did not provide the correct answer to a given question, the lecturer was able to recap on that particular aspect and rectify any misunderstandings. In such cases, further similar questions were posed to the class to determine if indeed such misunderstandings had been clarified.

In the test cases for this study, student submissions were also available for viewing on the host PC within the classroom, allowing for the responses to be seen by the entire class via the available overhead projector and screen, once all submissions had been received. This had the added advantage of allowing students to gauge their level of knowledge in comparison with their colleagues.

At the end of the lecture, for each group, paper questionnaires were used to obtain anonymous student feedback on the use of the new SDSRS. 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 from both the Computing and System Dynamics modules respectively.

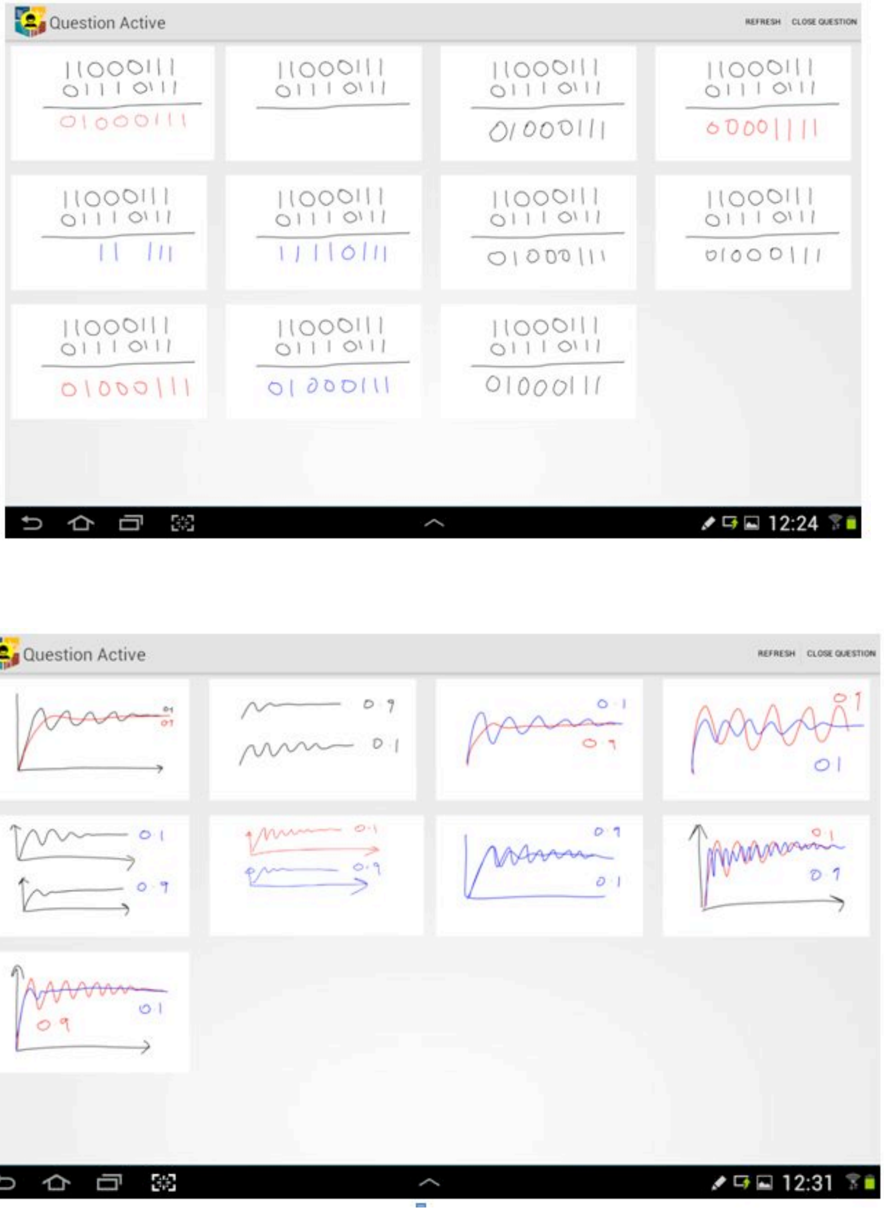

Figure 5 – Sample student responses received as part of the classroom evaluation for (a) the Computing class and (b) the System Dynamics class

3.1 Student Feedback

It is evident from Table 1 that the students, in general, found the sketch application quick, responsive and easy to use. They clearly felt that this system offered a great means of giving responses and interacting within the classroom. More significantly, they mostly felt that the freeform sketch style input was really useful. Overall, they felt that the response system made their learning more enjoyable and motivated them to answer the lecturer's questions. While both groups of students responded in a similar fashion for all statements, it is interesting to observe that the first year students were slightly less favourable, on average, in all instances. This can be partly attributed to the fact that one of the first year students seemed to have had a negative experience with the system (i.e. the student application did not perform as expected) and, thus, responded negatively across most of the statements.

Additional feedback was also obtained from the questionnaires via comment boxes. Here, students were given the opportunity to comment on their favourite aspect of the system and on how the overall system could be improved. From the feedback obtained, the students noted that the system was a "good way to interact" with one student stating that it "makes class interaction more fun." More importantly, several appreciated the flexible input offered by the new system stating that "you could draw whatever you like" and "you weren't bounded to specific formats."

The most overwhelming response related to the anonymity aspect of the system with several students noting that they were able to "answer questions without being singled out" and that they were no longer "afraid to be wrong". Interestingly, this issue appeared to be of more concern to the first years as 7 of the 13 students noted anonymity as one of their favourite aspects of the system. In comparison, only 3 of the 13 second year students responded in a similar manner.

	First Year Computing (13 Students)		Second Year System Dynamics (13 Students)	
Statement	**Average rating (1-5)**	**Std. dev.**	**Average rating (1-5)**	**Std. dev**
I found the app easy to use	4.5	0.9	4.7	0.5
I felt the app was quick as responsive	4.3	0.6	4.5	0.5
The app performed as expected	4.1	0.9	4.5	0.5
The app provided a good way to interact in class	4.6	0.9	4.8	0.4
The app provided a good way to give feedback/responses	4.6	0.9	4.8	0.4
The flexibility of providing a sketch is really useful	4.4	0.8	4.6	0.5
The use of the response system makes my learning more enjoyable	4.3	0.6	4.8	0.6
I was motivated to respond to the lecturer's questions using this system	4.5	0.7	4.8	0.4
I would like to use this response system again	4.5	0.7	4.8	0.4

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

In terms of possible improvements to the system, students requested the use of additional colours for sketching. Currently they have three possible colours to choose from but some students felt that there should be more. They also felt that an electronic pen or stylus would be more beneficial and allow them to draw better sketches. During the evaluation students used only their fingers, which some students found "too cumbersome." This issue was more evident in the feedback from the first year students, but this can likely be attributed to the fact that they had more detailed writing in their responses (see Figure 5(a)) as compared to the relatively straight forward sketches by the second year students (see Figure 5(b)). In an effort to alleviate this issue, a zoom-in zoom-out option will be developed for future implementations to allow students to zoom-in on their sketch and, thus, allow them to provide more accurate representations.

Finally, some of the students liked the fact that they were able to receive feedback from the lecturer (again, in an anonymous fashion) and also found it interesting to see the responses of the entire class.

3.2 Lecturer Feedback

The two lecturers involved in the evaluation noted that the system was easy to use from their viewpoint. However, it should be noted that both lectures are members of the Department of Electronic Engineering at Maynooth University and are quite familiar with similar technology. It would be interesting to observe how staff members who are less familiar with such technology would find using the proposed smart device based response system. This currently remains an aspect of future work.

Both lecturers noted several positive aspects of this system. They found the use of the system beneficial for improving classroom interaction and for breaking up a potentially long lecture slot (some lectures can last for 2 hours at a time). They noted that the students seemed to engage well with the system and offered up responses to the various questions that were posed. They found the nature of the responses useful and insightful and allowed them to illustrate and focus on obvious errors that were made. They both agreed that such a response system was well suited for the engineering and related disciplines.

The lecturer of the Computing module noted one potential issue with the use of such a response system. Since all responses were anonymous, it opened up the possibility of students intentionally misusing the system. In fact, there were one or two instances where students submitted inappropriate sketches. However, such instances were minimal and short lived, as the lecturer can control whether or not to display student responses on the overhead screen. When such images are not displayed in class, and only the lecturer can view it, the students tend not to continue in this manner. It is worth stating that this seemed to be more of an issue with the first year students, as there were no such incidents noted during the evaluation with the second year students. Perhaps this is a reflection of the level of maturity of the two sets of students involved. However, this would need further testing, as no concrete conclusions can be drawn from the small numbers involved in the current evaluation.

Overall, both students and lecturers found the new student response system easy to use and extremely beneficial for promoting useful and meaningful interaction with the classroom. Both parties requested the use of this response system in future classes.

4. Conclusions And Future Work

This paper has presented a novel SDSRS that allows students to respond to questions, posed in a classroom, using a flexible freeform input in the guise of a sketch. This flexibility ensures that lectures can now attain pertinent information relating to the problem solving ability of the student. Information about the methodology employed by the students can now be obtained almost instantly and in real-time during a traditional lecturer class. This, in turn, can provide a higher quality active learning experience for the students involved, especially in the science and engineering disciplines where the capture of such information is fundamental to improving the students' knowledge of the relevant material.

An initial evaluation of this system has shown that students find it easy to use and appreciate the fact that it offers a freeform style input for responding. They also note that the anonymity of the system is an important factor in their engagement with material. The lecturers who have used this system to date have also found it easy to use and find the information that they can obtain from the students is highly useful and extremely insightful. Both students and staff requested continued use of this system within their programme of study.

Future work involves extending the use of the SDSRS to other non-Android based platforms. In addition, it is hoped that this system can be evaluated across a range of different disciplines.

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