Design, Implementation and Evaluation of a Tablet-based Student Response System for an Engineering Classroom

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Abstract – Student response systems (SRSs) have generated significant debate and discussion in the educational research literature in the past decade. It is well known that they offer several important advantages including encouraging student interaction, offering anonymous and instant student feedback and improving the student learning experience. While several different types of such systems exist, they nevertheless remain limited in their input capabilities. In particular, they typically only allow for multiple-choice style responses, although some devices do cater for numerical and textual input. However, most of the available SRSs do not allow for freeform input such as mathematical equations, graphical drawings or circuit diagrams. This is of particular relevance to Engineering and Science disciplines where such information is core to the student learning. The approach to solving a problem is often as important, if not more so, than the actual final answer itself. This paper presents a classroom response system that allows for freeform input and operates on any smart media device with a touch interface and that employs the Android operating system, such as everyday smart phones and tablets. The proposed system involves three different components, namely a student application that allows for sketch capabilities, a lecturer application that allows for the viewing and marking of multiple student sketches and a cloud service for the exchange of messages. In addition, this proposed system was evaluated by a class of engineering students at NUI Maynooth, the results of which are presented within.

Keywords – Student Response Systems, Engineering Education, Student Interaction, Smart Devices

I INTRODUCTION

Student response systems (SRSs) have increased in popularity over the past decade, with their use in the classroom steadily increasing. These systems exist in educational literature under many different guises [1], including audience response systems [2], classroom response systems [3], voting machines [4] and, more recently, Clickers [5]. All such systems are very similar in nature [5, 6], 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 interprets the responses and presents them in a convenient and useful form. An example of one such system is presented in Fig. 1.

The research literature clearly illustrates the many pedagogical benefits and educational uses 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 [5, 7-10]. In addition, SRSs can be used for student assessment and obtaining anonymous student feedback [7, 11].

However, while several different types of SRSs exist, they have limited input capabilities. Most devices, such as the one shown in Fig. 1, only allow for a multiple-choice input, whereby students select from a set of possible answers to a posed question. Some devices do allow for a numerical or textual-based submission. However, most of these devices do not allow 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. 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 on the students' grasp of such methodology, then is necessary for a SRS to facilitate freeform input.

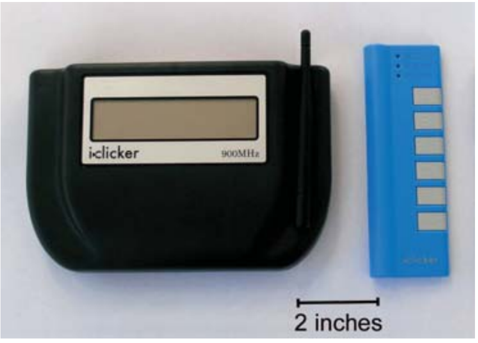


Fig. 1: iClicker receiver (left) and transmitter keypad (right) [5]

In this paper, we propose the use of a smart device based SRS to overcome the aforementioned problem. Here, we focus on smart devices using the Android operating system. More specifically, we primarily employ the Samsung Galaxy Tab 2.0 tablets for evaluation purposes. However, smart phones, as owned by most of the students, are also used in the evaluation process. A somewhat similar solution has previously been proposed by [12, 13]. In this case, their work has focused on the HP Tablet-PCs and generally requires a software tool, such as Powerpoint, to develop a set of slides with which the lecturer and students can interact. Here, we use standalone applications that do not require any such commercial software tools, and moreover, can be used on any smart media device using the Android operating system. This also provides a cost-effective solution as it easily integrates with students' own smart phones, or other suitable smart media devices that they may be using.

Our solution consists of a student sketch application, a lecturer 'view and mark-up' application and a cloud-based service for co-ordinating between these two applications. The student also has the option of viewing any individualised corrections made by the lecturer, if need be. This system was evaluated by a class of Electronic Engineering students at the National University of Ireland Maynooth. Initial feedback from the students was very positive.

The rest of the paper is structured as follows. Section II outlines the design of the tablet-based student response system. Key operational features of this system are illustrated in section III, while section IV presents the results of a classroom evaluation study. The use of the system on smart phones is also evaluated. The paper concludes with some ideas for future work in section V.

II DESIGN OF THE SMART DEVICE SRS

The key idea of this Smart Device system is to provide a classroom of students the means of responding to questions in a flexible manner, while maintaining a certain level of anonymity. In addition, it allows the lecturer to obtain instant and highly appropriate (in the context of Engineering and Science) feedback of the students' knowledge of a given topic. While this system is developed for a classroom context, it is clearly applicable to a wider market. In particular, it is suited for any scenario that involves a presenter and an audience, where the presenter may wish to poll the audience for their response to a given topic.

The design of our system is based on two main use cases, as follows:

(1) *Classroom response* – This works in a similar manner to existing Clickers. A lecturer presents a question to a class of students either verbally or in written form, such as on a whiteboard, for example. The students individually, or as part of a team, attempt to solve this question by sketching on their tablet, or equivalent smart device. When finished, the students submit their solution. The lecturer can then access all submitted solutions (in the form of images) from his/her tablet and/or local pc. The lecturer can quickly glance through these images, ascertain how well the class have grasped the relevant knowledge and respond appropriately.

(2) *Assessment and feedback* – In this use case, a lecturer sets the class a series of assessable tasks. Each student completes each of these tasks in a timely fashion on their tablet. The students submit their solutions before the end of the allocated class. Later, outside the class, the lecturer can access all the solutions from all the students on his/her tablet. S/he can assess each submission and offer formative feedback, via adding comments and/or highlighting errors. On completion, s/he can upload the corrected material back to the central server. The students can then subsequently download their own corrected assessment and obtain feedback on where they may have made mistakes, if any.

These use cases may be implemented by an SRS with three key components, namely a student application (henceforth referred to as the student app), a lecturer application (henceforth referred to as the lecturer app) and a central service that can communicate with both these applications. The main functional requirements of each of these components are now outlined.

a) The student app

This is the simplest of the three system components and requires basic sketching capabilities for the student to use. Here, it was decided, to limit the available sketch options in order to make the application easy to use, while remaining perfectly functional. In order words, we did not want students spending time 'playing' with various nice (but not absolutely necessary) features that other similar sketch applications typically offer. Instead we wanted them focused on the primary task at hand, i.e. solving the problem posed by the lecturer. In addition, as we intend using tablets and similar smart devices, the touch screen provided the only means of input to the system.

b) The lecturer app

The key requirement for this application involved having good viewing capabilities. In other words, how does one view multiple images in a quick and easy manner? Two options were chosen, based on ideas taken from photo-management applications. Here, the lecturer could view all the images in the form of a grid (with scroll function if need be), as in Fig. 5. When the lecturer selects a particular image to analyse, the view changes to a two-panel window, where the side panel contains a scrolled-list of all images and the main panel shows the actual selected image, as in Fig. 6.

The lecturer app would also have all the same editing functionality as the student app, so that they may add comments to various images if need be.

c) The central service

This is the hidden component of the system from a user's point of view. It co-ordinates the exchange of responses between the student and the lecturer, and marked-up edits back to the students.

For this system, we use a cloud based service, deployed using the Google App Engine, to perform the relevant exchange of responses. In doing so, it allows us to work with non-Android systems in the future. As such, suitable student and lecturer applications could be written for other devices, such as the iPad and the iPhone, which would seamlessly integrate with our current student response system.

III IMPLEMENTATION OF THE SRS

While the previous section outlined some of the fundamental design requirements of the proposed student response system, this section details the actual final implementation of the system. In other words, we now present the user interfaces of both the student and lecturer application.

a) The student app user interface

When a student selects the student app on his/her tablet, they are initially presented with a blank canvas with various sketch options as shown in Fig. 2 below. The menu options have been enlarged for viewing convenience. Here, the default setting is sketch mode using a black font. Students may select red or blue also. The erase function allows the students to delete any part of their sketch while the clear function deletes the entire sketch.

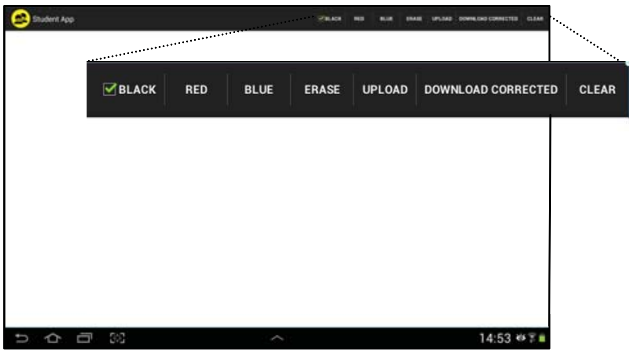


Fig. 2: Initial screen on opening student application, with menu options enlarged for viewing convenience

An example sketch using the student application is given in Fig. 3. Here, the sketch represents a typical Karnaugh Map solution used in modules involving digital logic minimisation.

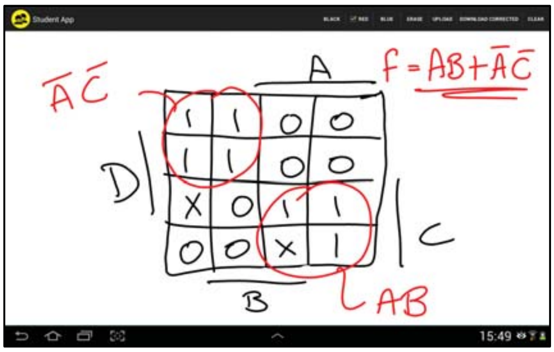


Fig. 3: A sample student submission

The student can use the upload function to submit their sketch to the cloud service. At a later point in time, the student can select the 'download corrected' menu option and, provided corrections have been applied by the lecturer, they will obtain a non-editing jpeg image of their work. If no corrections have been made then a pop-up message will inform the student of this simple fact. Fig. 4 shows an example of a corrected student submission, as viewed by the student app. Note, that there are currently no menu functions available in this case. If desired, a student may save this image to their local device via the device's own screen capture software.

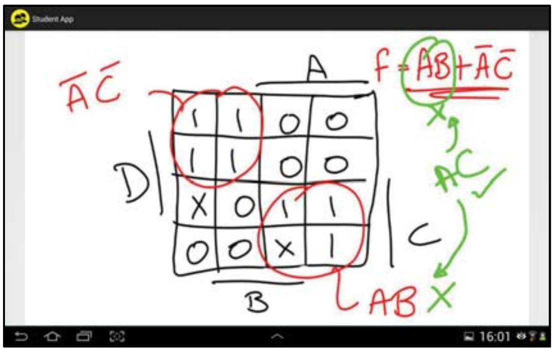


Fig. 4: A 'corrected' student submission – here, the lecturer has corrected the submitted work shown in Fig. 3

b) The lecturer app user interface

When the lecturer app is opened, the lecturer has the option of downloading all the images on the server (for the assessment and feedback use case example) or downloading the most recent images (for the classroom response use case example). The latter refers to the case where a student may attempt a problem several times and, while all uploaded attempts are stored on the server, the lecturer is only interested in their last attempt. Hence, 'recent' in this case, refers to the last submission of each student in the classroom. Images are downloaded in a grid format, as illustrated in Fig. 5.

The 'delete all' allows the lecturer to clear all the images off the cloud service whenever they wish to do so (typically at the end of the class).

By selecting one of the images in the grid, the view then changes to a two-panel window, as shown in Fig. 6. Here, all the images are still easily accessible on the left panel, while the selected image is shown in the main panel. The menu options have also changed to allow the lecturer to mark the image and add comments, etc. Upon completion the lecturer can save the changes made to the image. By selecting the upload option, the corrected image is sent back to the server so that the student can download it at a later stage. The lecturer may instead choose to mark several of the images and then upload all corrected images at the end.

One other simple feature worth noting is the addition of the green colour available in the lecturer app, in comparison to the student app. This is simply to ensure that the lecturer has a distinct colour for marking, so that any comments or corrections made to a submission by the lecturer are easily identified by all parties involved.

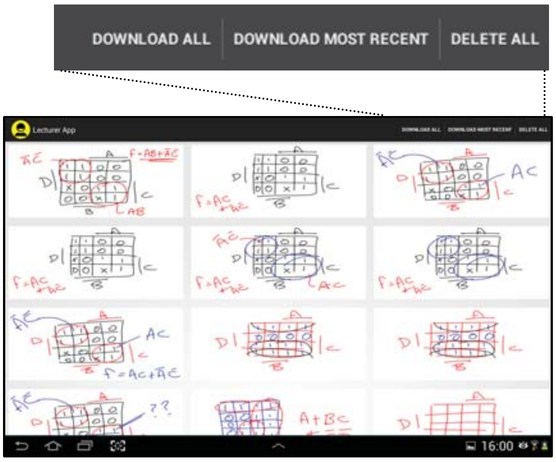
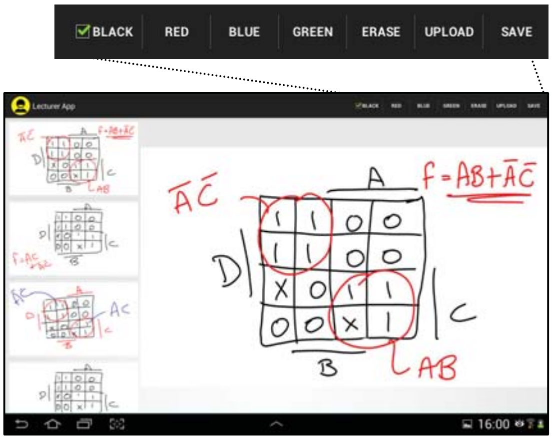
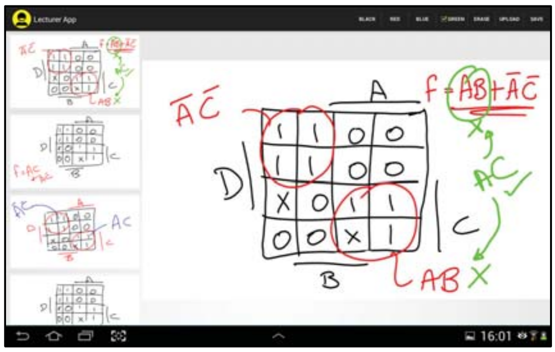


Fig. 5: Screenshot of downloaded images on lecturer's device, with menu options enlarged for viewing convenience



(a)



(b)

Fig. 6: Lecturer app in 'marking' mode, with menu options enlarged for viewing convenience: (a) shows student's submission from Fig. 3 and (b) shows lecturer's corrections (see Fig. 4 for student view of same)

IV CLASSROOM EVALUATION OF THE SRS

Two different preliminary studies were carried out to evaluate our smart device student response system. One study related to students using this system (on tablets) in a classroom context while the other study considered how students, in general, found using the student sketch application on their smart phones. Results from each of these studies are now presented.

a) Classroom evaluation

The proposed system was initially used by a group of second year students on the BE in Electronic Engineering degree programme at NUI Maynooth. The group in question comprises four female and nine male students. Three of the group are mature students and two are international students. The tablet-based response system was used in one of their lectures, in accordance with Use Case 1, as outlined in section II of this paper.

Students were presented with different questions at various times throughout the lecture and the responses were collated and viewed in real-time on the host PC, so that the students could view their responses via the overhead projector and screen. The questions related to material covered in the class and required students to answer with suitable sketches. For example, students were asked to sketch the typical step responses of a second order system with damping values of 0.1 and 0.9 respectively. Some sample student responses are given in Fig. 7.

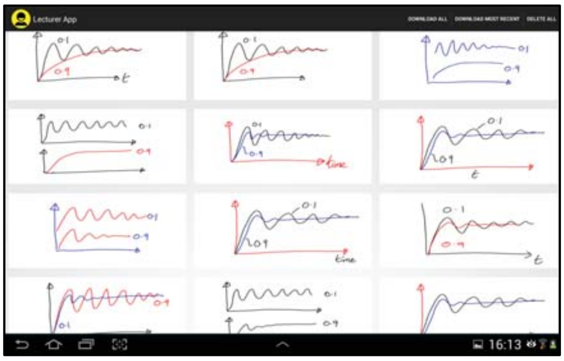


Fig. 7: Sample student responses from evaluation study

On completion of the lecture, students were surveyed for their views using paper questionnaires. The key results and findings can be summarised as follows. Table 1 shows the average and standard deviation of the ratings given by the students' for a range of statements, as shown. Students were asked to rate each statement on a scale of 1 (strongly disagree) to 5 (strongly agree).

It is worth nothing that the students found the student application easy to use and navigate with no prompting required. The all liked the overall system and found the concept and application both simple and useful. Most felt it made their learning experience more enjoyable and, moreover, wanted to use the system in future classes. In terms of additional feedback obtained, via comment boxes, some students noted that the system was a "*good way to interact*" and allowed them to "*answer questions without being singled out*." Such findings clearly correlate with those in the literature, as detailed in the Introduction section.

Table 1 – Classroom evaluation results. 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	4.7	0.5
I felt the app was quick as responsive	4.5	0.5
The app performed as expected	4.5	0.5
The app provided a good way to interact in class	4.8	0.4
The app provided a good way to give feedback/responses	4.8	0.4
The flexibility of providing a sketch is really useful	4.6	0.5
The use of the response system makes my learning more enjoyable	4.8	0.6
I was motivated to respond to the lecturer's questions using this system	4.8	0.4
I would like to use this response system again	4.8	0.4

More importantly, students found the idea of responding with sketches useful, flexible and a good means of giving feedback and interacting in class.

Students were also asked to consider possible improvements to the student application and most suggestions related to adding more colour options and having an undo button. They also felt that the use of a stylus (or electronic pen) would make sketching easier for them. In the current setup, they were required to use their fingers only.

One other interesting feedback that several students reported was the lack of a 'dot' facility within the app itself. In other words, simply tapping the screen was not enough to create a dot. A little motion is required in order to obtain a dot image. This is a general issue associated with the sensitivity of the hardware and not specific to the sketch app itself.

The classroom response system was also presented to several different lecturers in the Dept. of Electronic Engineering. They were then asked to evaluate the lecturer application. Verbal discussion with these staff members revealed that most of them found the application easy to use. They really like the idea of being able to add markings to the students' responses and sending them back to each student individually. In general, they found the concept of the response system useful and felt that offering the students sketch-based input capabilities was important and necessary for engineering and related disciplines. More importantly, several of the staff would like to make use of this system in their own lectures.

b) Smartphone evaluation

In this case, 16 different students, from the Departments of Electronic Engineering and Physics were surveyed on their use of the student app on their individual mobile phones. Here, it is only the student app and its use on the smart phone that is of interest, as this is independent of the overall response system. Students feedback was once again collected using paper questionnaires. Table 2 shows the average and standard deviation of the ratings given by the students' for a range of statements, as shown.

Table 2 – Smartphone evaluation results. 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	4.6	0.6
I felt the app was quick as responsive	4.7	0.5
The app performed as expected	4.6	0.5
The app provided a good way to interact in class	4.1	0.9
The app provided a good way to give feedback/responses	4.4	0.6
The flexibility of providing a sketch is really useful	4.5	0.8

As before, students felt the student app was easy to use and performed as expected. Although this was on their individual mobile phones, they felt that this was a good way to interact in a class and provided a good mechanism for responding and giving feedback.

In addition, the students were asked to comment on the advantages and limitations of using the student app on a smart phone as opposed to a tablet. For the most part, the comments were as expected. The overwhelming response was that the small screen size, in conjunction with the lack of a stylus (or the use of a relatively large size finger in relation to the screen size of a phone) limited the ability to draw more detailed and accurate sketches. Nevertheless, the students still felt that this was still useful as one could provide responses involving simple sketches and that the use of the mobile phone was more suited to "*bringing to class and more accessible*".

Interestingly, a few of the students had no problems with the sketch capabilities on their phones and felt that it worked just as well as it would on tablets. This is more likely true for students that have larger-screened phones.

Clearly, there is a trade-off between the size of the screen and the sketch capabilities available to the students. On the other hand, smart phones offer a more accessible and cost-friendly solution than their tablet counterparts, not least because most, if not all, the students possess smart phones.

V CONCLUSIONS & FUTURE WORK

This paper has presented a student response system that has freeform input capabilities, allowing for students to respond to questions with graphical sketches, mathematical equations, circuit diagrams, etc. The current system has been developed for use on tablets and smart phones with the Android operating system.

Preliminary evaluation results show that students are strongly in favour of the proposed system. They find the tablet-based version easy to use, like the flexibility that a sketch input offers and find it a useful, motivating and enjoyable response system to use in class. In addition, students have found that the smart phone version of the student app works reasonably well but that there is a trade-off between the size of the phone screen and the detail of sketch that can be rendered as a result. Nevertheless, it offers cost and accessibility advantages over using tablets.

Future work involves developing a student app and a lecturer app for devices supporting alternative operating systems, such as iPhones and iPads. We would also like to do a more detailed evaluation of this response system by employing it in a classroom environment for a full academic year.

VI ACKNOWLEDGEMENTS

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