An evaluation of UniDoodle : A highly effective Student Response System for the STEM disciplines.

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Abstract

Existing student response systems, such as Clickers, have limited input capabilities and lack the necessary features to gather the insightful and necessary information that is relevant in STEM-based disciplines, where the methodology is often more important than the final answer itself. Here, we propose the use of a new student response system, called UniDoodle, which uses tablets and smartphones to deliver a system that captures an extensive range of information in the form of sketches and annotations. Thus, information relating to equation solving, graph sketching, and diagram annotations can now be obtained in large classes in a quick, convenient and user-friendly manner. This information is obtained in real-time allowing for teachers to respond immediately to any issues that may arise in their students' understanding of material. In this paper, we summarise the key features of the UniDoodle system and we carry out an extensive evaluation of its use in a live classroom environment. The context of the evaluation and the feedback obtained are presented within.

Keywords: Student response systems; formative feedback; real-time feedback; high quality feedback.

1. Introduction.

Formative feedback is an important part of the student learning process. By monitoring students' learning on an on-going basis, teachers can obtain feedback to improve their teaching. Students can improve their learning by identifying their strengths and weaknesses. In addition, they can

address their weaknesses with the aid of follow-on feedback from the teacher. This is a recognized and valuable part of the learning cycle and, unlike its summative counterpart, formative feedback does not penalize the students for lack of knowledge and understanding.

In the past two decades, developments in technology have aided this learning process, allowing teachers to monitor students' learning in a more efficient and timely manner, with the latter being particularly relevant to students. Student response systems (Fies & Marshall, 2006; Blood & Neel, 2008) are a class of technology that falls into this category. They exist under many difference names including audience response systems (Miller et al., 2003), classroom response systems (Roschelle et al., 2004), classroom communication systems (Beatty, 2004), voting machines (Reay et al., 2005), personal response units (Barnett, 2006) and, more recently, clickers (Barber & Njus, 2007; Lantz, 2010) and clicker assessment and feedback technology (Han & Finkelstein, 2013). Response systems such as clickers have been used 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.

The student response systems all operate in a very similar manner, as follows. The teacher poses a question in class and presents the students with several possible answers, akin to MCQs. The students then use their handheld device to select one of the given answers. The teacher can then collect these answers in real-time and, using appropriate software, obtain a summarized view of their class's response. These systems typically allow students to respond in an anonymous setting (Graham et al., 2007). The research literature outlines many of their pedagogical and practical benefits and include improved interaction and motivation, improved student learning, increased student preparation for class, improved attendance and increased student satisfaction (Skiba, 2006; Barber & Njus, 2007; Caldwell, 2007; Auras & Bix, 2007, Moredich & Moore, 2007; Bruff, 2009; Blasco-Arcas, 2013). Student response systems also ease the implementation of action learning activities (Sarason & Banbury, 2004) and classroom assessment techniques (Angelo & Cross, 1993; McLoone et al., 2015).

However, despite all these recognized capabilities of student response systems, they nevertheless remain limited in their input capabilities and are largely ineffective in STEM-based disciplines. In such disciplines, the methodology is as important, if not more so, then the actual answer itself. For example, consider the solving of an algebraic equation – students carry out this methodology and then, using current student response systems, choose one of the answers presented by the teacher. If students choose the wrong answer, then what exactly can we

conclude from this? We have no knowledge of what they did wrong – perhaps it was a simple calculation error or they simply chose the wrong answer. Were they even able to start the process of solving the equation? This information is highly relevant to the teachers in STEM disciplines and necessary in order to provide more effective feedback to the students. In addition, what if the students submit a correct response? In this case, it is assumed that they can solve the problem. However, how do we know that they did not simply guess the answer; did they happen upon the correct answer by mistake; or have they solved the problem in an alternative fashion, something that would be well worth sharing with their peers?

Existing student response systems also have logistical issues in relation to equipment requirements – does the teacher bring all the hardware to class (a handheld device for each student)?; should students purchase or hire the handheld device and, if so, what happens if they lose or misplace it?

The advancement of tablet-based technology and, more generally, smart devices (including smart phones) has opened a world of opportunities for student learning in the classroom environment. In particular, these mobile touch-screen devices offer a technological solution that allows student response systems to be developed to overcome the aforementioned drawbacks of existing solutions. UniDoodle, a recent development in this area, is a smart-device based student response system that allows students a more flexible input mechanism, in the form of sketching, on their tablet and/or smartphone (McLoone et al., 2016). It then collates these sketches in an efficient and user-friendly format for the teacher to view and edit. This offers a range of new and exciting possibilities for teachers in terms of obtaining deeper and more insightful feedback in relation to their students' knowledge of the material covered. Equations, graphs, annotations, etc. are now all possible and it is up to teachers to devise appropriate questions to extract the key methodology aspects in relation to the class material being taught.

In this paper, we employ and evaluate UniDoodle in two quite different classroom environments, namely a first year electronic engineering class in Maynooth University in Ireland and two first year mathematics classes in The University of Queensland, Australia. A detailed breakdown of the evaluation and the feedback obtained, from both the students and lecturers involved, is provided within. Prior to this, key features of the UniDoodle are presented for the convenience of the reader.

1.1. A brief overview of UniDoodle.

The UniDoodle response system consists of a student application (app), a teacher app and a Google-app engine cloud-based service that allows communication between the two apps. The system can currently operate on iPads/iPhones and all Android-based devices. The student app (Figure 1) allows for freeform input through sketching capabilities, thus allowing students to write equations, draw diagrams, etc. The app itself offers limited functionality to students for the purposes of simplicity and to avoid unnecessary distraction. Students simply need to be able to sketch their response, submit their response and receive edited responses from the teacher and, as such, this is all that the student app caters for.

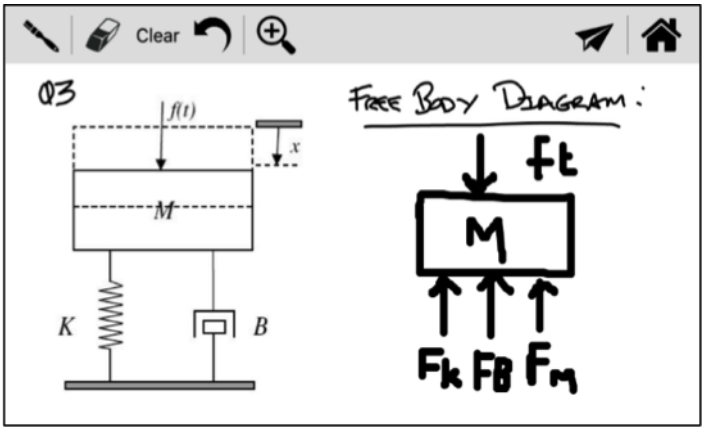

Figure 1: UniDoodle student app with sketching capabilities.

The teacher app, on the other hand, has significant more functionality and places the teacher firmly in control of the use of the UniDoodle system. It is the teacher that decides what question to use, when to use it, when to allow students to respond and when to close questions so that students are no longer able to respond. The teacher app has both viewing and editing capabilities. The teacher can view numerous answers in a grid format as shown in Figure 2 and can subsequently view and edit any of the responses, as in Figure 3.

Additional functionality includes (i) a filter option that allows teachers to remove inappropriate responses that students may submit, (ii) a template manager (Figure 4) and editor (Figure 5) that allows teachers to design questions in advance of class and store them on the cloud-based service and (iii) a web page for uploading template questions, thus allowing teachers to create detailed images on their own PC or laptop and then use these with the UniDoodle system. Further details of these features can be found in McLoone, et al. (2016).

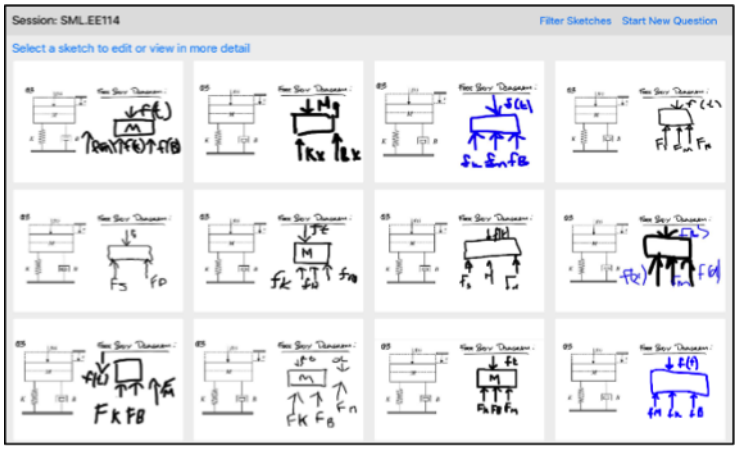

Figure 2: UniDoodle teacher app in viewing mode

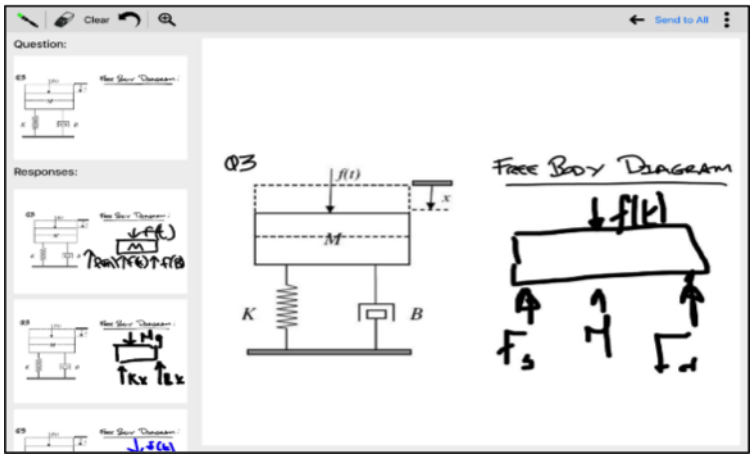

Figure 3: UniDoodle teacher app in editing mode.

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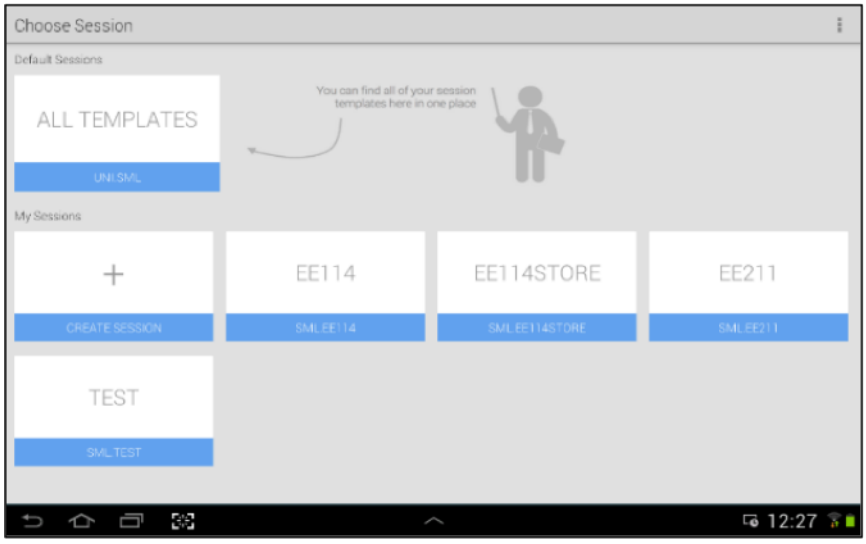

Figure 4 – UniDoodle teacher app showing template manager

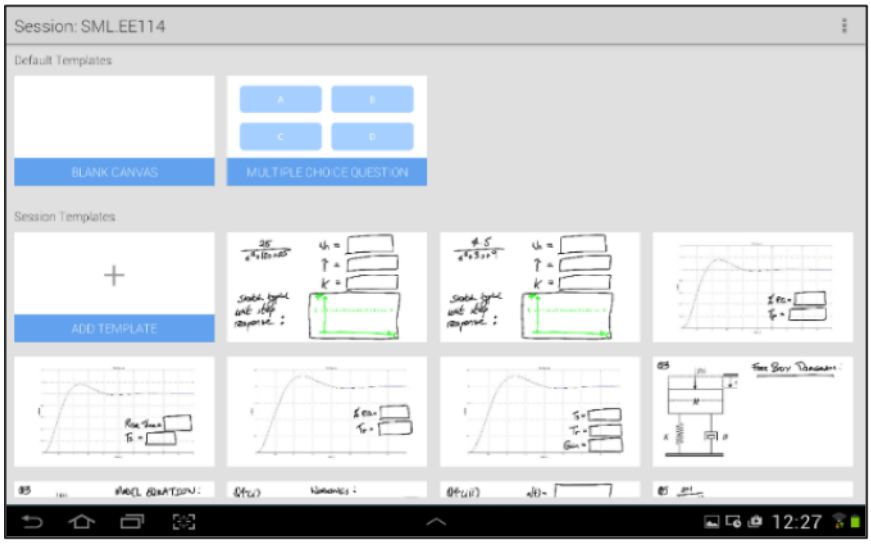

Figure 5 – UniDoodle teacher app showing template editor.

The UniDoodle system operates as follows – (1) the teacher presents a question to the class; (2) the students receive this question on their individual devices (typically their smart phones) and then respond anonymously using the in-built sketch capabilities (equations, diagrams, graphs, and annotations are all possible); (3) the teacher receives the student responses in a concise format on their own device (typically a tablet); the teacher may use the filtering option at this point if need be; and (4) the teacher gives feedback, if necessary, based on any obvious errors that students may have made. Student responses can be shown on the overhead

projector allowing all students to see all submitted responses. This offers students a level of peer learning as they can now see where other students are making mistakes, if any, and what those mistakes are. It should be noted that the teacher has the option of verbally posing a question in class (or writing one on the board), in which case, students are sent a blank template on which to respond. The teacher also has the option of a polling-style question, akin to the functionality that current student response systems provide.

The research questions guiding the study reported in this article were:

1. How is UniDoodle perceived by students in terms of usability, engagement and learning?

2. What benefits, if any, do teaching staff believe UniDoodle brings to tertiary STEM education

2. Methodology.

The UniDoodle system was evaluated in two quite different contexts, although both fall within the STEM disciplines. The first evaluation took place in a module on Systems and Control, which is a first year subject taught as part of the Bachelor of Electronic Engineering programme at Maynooth University (MU), Ireland. This module introduces students to the basic concepts of system dynamics, system modelling, feedback control and control design and prepares them for further modules in the area of systems and control. The class size consisted of 65 students (average attendance was ≈ 40) and the module in question was taught over a 12-week period. UniDoodle was used extensively throughout this module. Each class hour was divided into two parts with a conventional lecture taking place in the first part and then UniDoodle was employed for revision purposes in the second part of the class. A sample question used in the class is shown in Figure 6 overleaf.

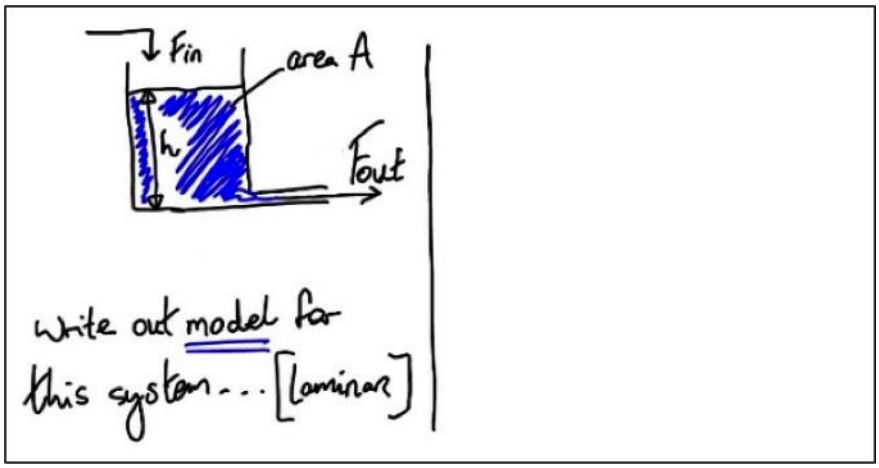

Figure 6 – A sample of UniDoodle-based questions used in the Systems and Control module.

The second evaluation took place in two different first year Mathematics modules taught by the School of Mathematics and Physics at The University of Queensland (UQ), Australia. The first 13-week module (≈ 200 students enrolled with an average attendance of ≈ 60) covered basic mathematical concepts useful in a wide range of discipline areas, including agriculture, arts, business, health sciences, science, social sciences, applied science and engineering. It includes topics from algebra to introductory differential and integral calculus. The second module (≈ 500 students enrolled with an average attendance of ≈ 250) involves calculus and linear algebra to support further studies in pure and applied sciences, engineering, finance or further mathematics pursuits. In both modules, UniDoodle was used at the start of several lectures with the view of revising the previous lecture's work. Some example questions used here included:

(a) solve for x if $2x + 3 = 3x - 4$,

(b) sketch $y = 3x + 4$,

(c) determine $\int \ln(x)\, dx$ and

(d) determine $\int_{-1}^{1} \frac{1}{x^2} dx$.

At the end of all the modules, students were asked to complete a detailed Likert scales questionnaire covering three key aspects of using UniDoodle, namely its usability, its effect on engagement within the class and its effects on learning. Students were also given the opportunity to provide additional comments on the use of UniDoodle in the form of freeform questions. The same survey was used in all cases. The results from the completed

questionnaires are summarized and discussed in the next section. In addition, the lecturers (and also co-authors of this paper) also give their thoughts and opinions on UniDoodle, which are presented later. It is worth stating that the lecturer of the mathematics modules had never used the UniDoodle system before the evaluation, but had used clickers previously.

Ethical approval for the work in this paper was obtained from both universities involved. In brief, participating students were informed of the research work in relation to their use of UniDoodle in the classroom and their consent was acquired. There were no mandatory questions on the surveys used and participation by students was entirely voluntary – there was no reward for participation. A paper-based survey was used in all cases. Finally, there were some students who did not have access to UniDoodle as they did not have a suitable phone/tablet (or forgot to bring their phone to class). In those cases, students could work with their colleagues and submit a joint response. Furthermore, as the question was presented in class, the students could always carry out the question on paper and see if they got the correct answer afterwards. Interestingly the vast majority (≈ 97%) of the attending Electronic Engineering students in Maynooth University had access to the UniDoodle app during class, in comparison with approximately 50% of the attending Mathematics students in The University of Queensland.

3. Results and Discussion.

3.1 Student Feedback.

A total of 139 questionnaires were completed: 34 (≈ 85% of average attendance) from The Maynooth University students in Ireland (henceforth referred to as MU) and 105 (≈ 15% of average attendance) from the University of Queensland students in Australia (henceforth referred to as UQ). Figure 7 - 9 show a series of histograms which summarize the breakdown of the responses obtained for a range of statements. Figure 7 presents the results pertaining to usability, Figure 8 relates to engagement and Figure 9 relates to learning. All results are presented separately for each cohort of students (the electronic engineering and the combined mathematics) for comparison purposes. The horizontal axis on each chart contains the numbers 1, 2, 3, 4 and 5 which correspond to strongly agree, agree, neutral, disagree and strongly disagree respectively. Hence a rating of 1-2 represents an overall agreement for a given statement.

A quick glance at all the student feedback shows that the two cohorts of students are generally in agreement across all aspects of the questionnaire.

3.1.1 Usability

In terms of usability, the feedback presented in Figure 7 (p.11) clearly shows that the majority of students who responded found the UniDoodle system easy to use and required little or no help to use it. This is worth highlighting, as UniDoodle currently has no built-in help and relies solely on the intuitive nature of its key features. In addition, there were very few technical issues associated with the use of UniDoodle. UniDoodle does rely on the availability of a good Wi-Fi connection, but technical aspects in this regard lie outside the realms of the UniDoodle system.

Most students used the UniDoodle app on their own smartphones in the classroom and, as such, screen size can cause potential issues with regards reading and responding to questions. However, it is interesting to note that despite such issues, 80% of the UQ and 97.1% of the MU student responses found the text and graphics legible

3.1.2 Engagement

As often noted throughout the literature, classroom interaction and engagement is an important aspect of the student learning process, not least because it helps maintain and prolong the attention span of students. The literature also indicates that the use of classroom response systems certainly helps in this regard as they encourage class participation and offer plenty of opportunities for feedback and in-class discussion (Siau, et al., 2006). The student feedback received in relation to the use of the UniDoodle student response system clearly confirms these findings (Figure 8), as 83.8% of the UQ and 97% of the MU student responses agreed that using UniDoodle helped them to be active in class and, furthermore, 83.8% and 96.9% respectively found this method of interaction effective.

3.1.3 Learning.

From Figure 9 (p.13), we see that students generally felt that the use of UniDoodle enhanced their learning experience. This is particularly evident with the electronic engineering cohort with over 90.9% of the MU student responses agreeing with this statement as compared with 62.9% of the UQ student responses. As we know, feedback is an important aspect of the student learning experience. The use of UniDoodle allows the teacher to offer high quality and effective feedback in real-time to their students. It is important that the teacher gives this feedback,

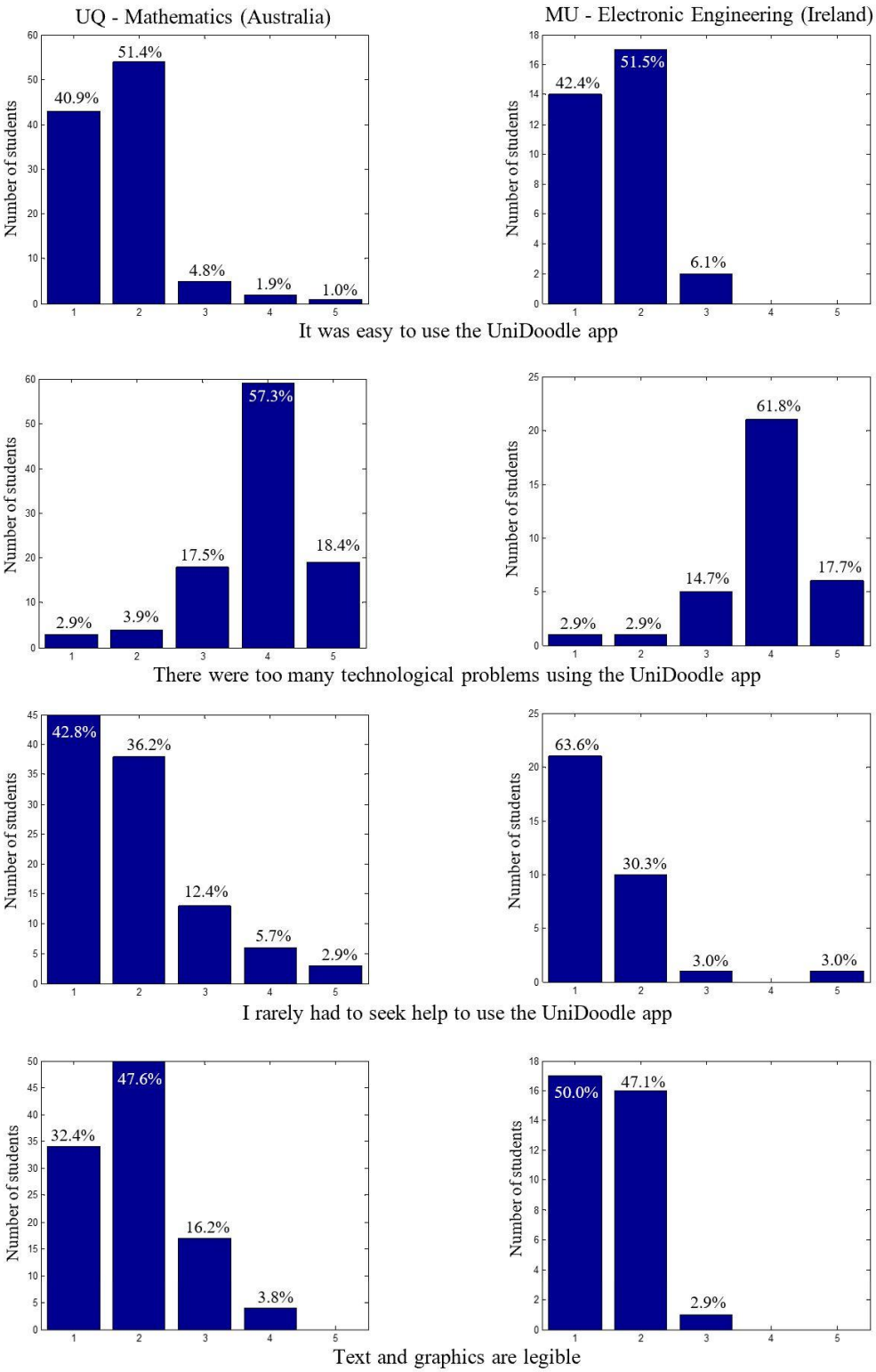

Figure 7 – Survey results on the usability of UniDoodle. The numbers 1 to 5 on the horizontal axis of each chart represent strongly agree, agree, neutral, disagree and strongly disagree respectively.

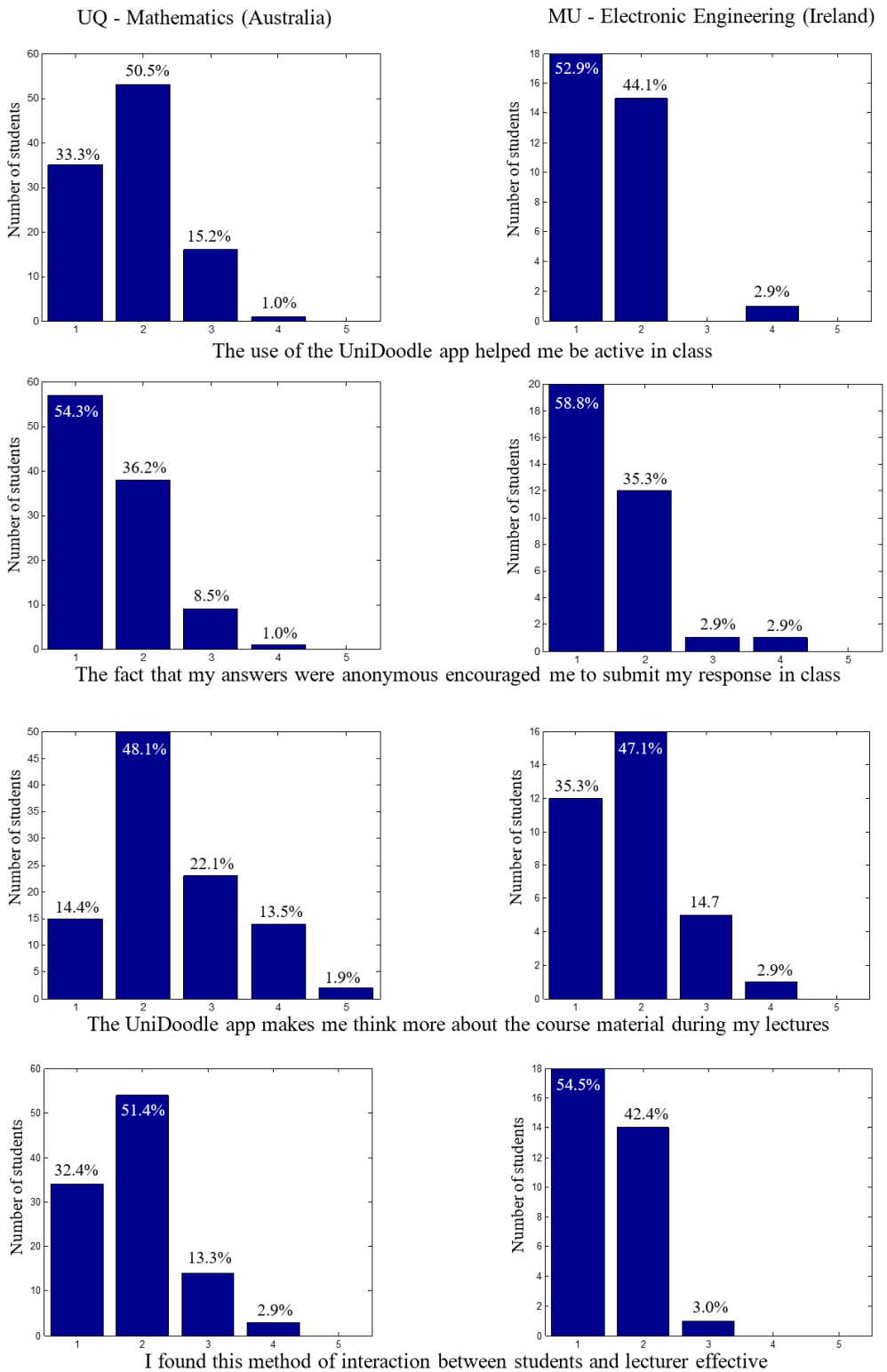

Figure 8 – Survey results on classroom engagement by using UniDoodle. The numbers 1 to 5 on the horizontal axis of each chart represent strongly agree, agree, neutral, disagree and strongly disagree.

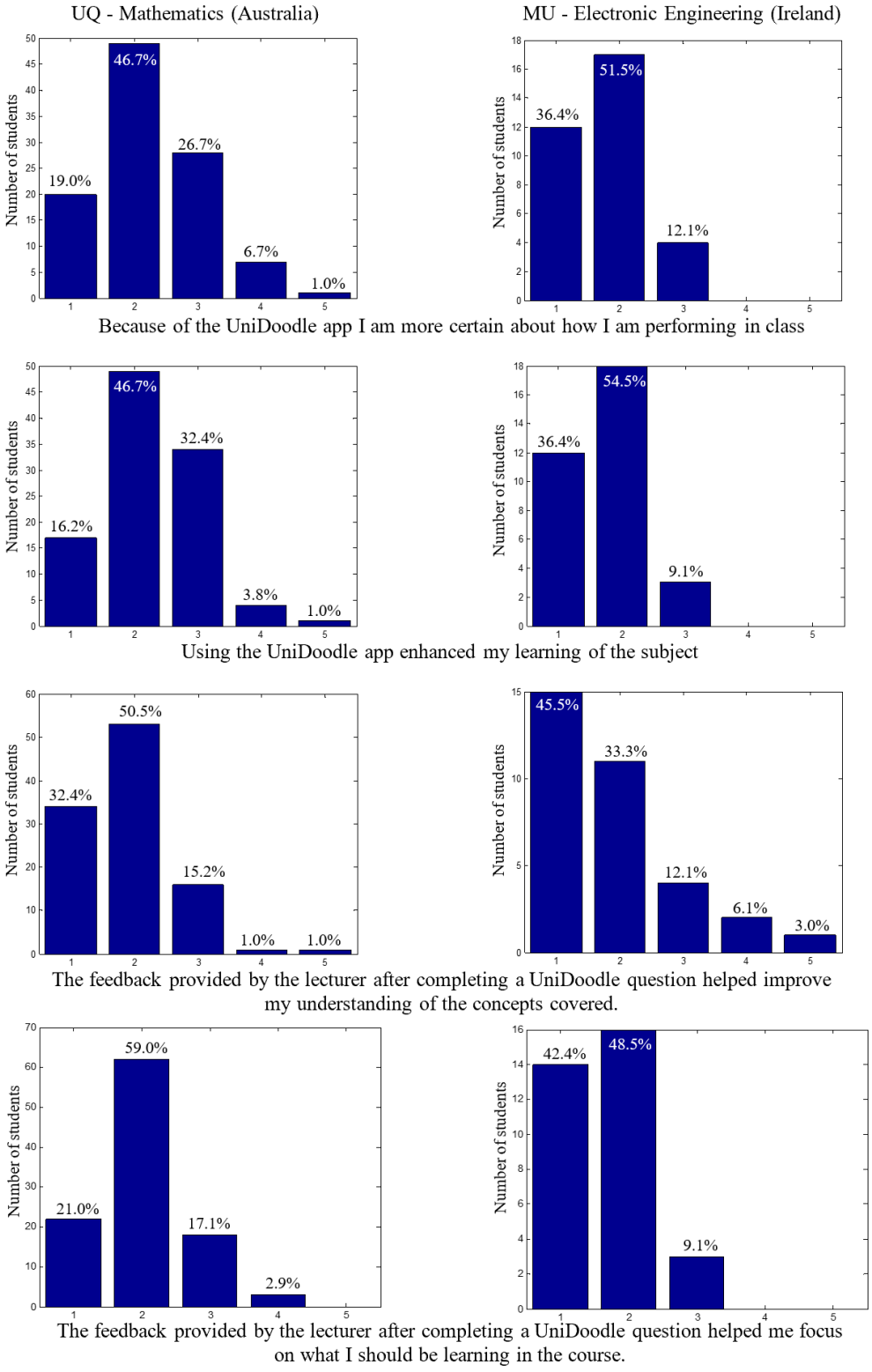

Figure 9 – Survey results on learning by using UniDoodle The numbers 1 to 5 on the horizontal axis of each chart represent strongly agree, agree, neutral, disagree and strongly disagree respectively.

otherwise the use of UniDoodle becomes a limited and potentially pointless exercise. In the case of the student feedback, we can clearly see that students appreciate the teacher feedback, particularly in terms of improving their learning. 80% of the UQ and 90.9% of the MU student responses felt that the feedback from the teacher helped them focus on what they should be learning in the course, while 82.9% and 78.8% respectively felt that it helped improve their understanding of the concepts covered. This is further reflected in several of the students' comments. One student stated "*it helped me to understand what I was struggling with in the lectures and it gave me experience working out exam like questions and actually getting the instant answer*" while another student noted: "U*niDoodle app helps me to understand what I did not understand and made me practice maths*."

A majority, (65.7% of UQ and 87.9% of MU) student responses stated that, as a result of using UniDoodle, they were more certain about how they were performing in class. This in an important facet of using UniDoodle, and classroom response systems in general, as students are now aware of their performance relative to their peers. Sometimes, they can see that they are not the only ones struggling with certain concepts while, at other times, they might just realize that most of their colleagues are finding certain concepts easy and yet they are not. UniDoodle gives the added benefit of providing students with the possibility of seeing where and how mistakes are being made by them and by their peers.

Finally, some of the freeform responses obtained noted a positive motivational aspect of using UniDoodle. In particular, some of the students took pride in seeing their correct answers on the screen in the classroom and, as a result, were more attentive in class. One such student noted that "*UniDoodle is helpful because when you don't know something or get the wrong answer, you feel guilty when the answers are posted on the screen, which motivates me to learn the content.*"

3.2 Lecturer Feedback.

The lecturers (and co-authors of this paper) noted that the use of UniDoodle was enjoyable and rewarding. It breaks up the traditional teaching style of lecturing to the students and therefore reduces the risk of monotony. It promotes significantly more interaction within the classroom, as noted by the students themselves, and allowed for numerous opportunities for discussion via feedback given in reaction to student responses.

It was observed that the anonymous nature of the system meant that a significantly number of students were more likely to respond to questions than would otherwise have been the case. By removing the fear of being wrong in public, as UniDoodle does, students are more likely to offer some sort of attempt to a question in class. This aspect of UniDoodle is clearly evident from the student feedback also. It was agreed that the use of UniDoodle proved beneficial in providing the insight to the students' knowledge that the lecturers had hoped for. Using UniDoodle allowed them to illustrate, to their students, the mistakes that are so often made. In the past, one could always tell their students what the common mistakes were, but now the students get to visually see the mistakes for themselves. This offers significantly richer insight to the students as they are instantly able to experience the mistakes for themselves. Follow-up questions using UniDoodle generally showed that most students had indeed learned from their mistakes and did not repeat them in later questions. It seems to be a case of "s*eeing is believing*" for the students. Interestingly, it was one of the students who commented that it was "*good to learn from*" one's "*own mistakes*."

The mathematics lecturer, who had not seen or used UniDoodle prior to the evaluation study, noted that it was easy to use for both himself and his students. As noted earlier, UniDoodle currently has no built-in help and relies solely on the intuitive nature of its key features. This applies to both the student and the teacher apps.

Finally, the mathematics lecturer felt that it is the rich information that it provides that is the real selling point of the UniDoodle response system. As a nationally recognized mathematics lecturer with over 20 years' teaching experience he used several response systems, but nothing compares to UniDoodle. Time is precious in lectures and the quicker one can understand where their students are mathematically, the quicker they can give them feedback and tailor their teaching to best suit their needs. "I *received helpful feedback on how I was going in the course*" is a standard question on module evaluation surveys at Australian universities. Of the 8-10 questions in the survey, students consistently rate this question the lowest. Giving timely and appropriate feedback can be difficult, especially in classes of up to 1300 students. However, UniDoodle makes this task much easier through the acquisition of rich information from the students which then allows the lecturer to give well directed feedback to the class straight away. As one student said, "*It must be difficult for a lecturer to identify common problem areas for a class. The UniDoodle app makes it obvious where students have trouble."*

4. Conclusions.

This paper has presented a detailed evaluation of a novel sketch-based student response system known as UniDoodle. This system offers a flexible input in the form of sketches and, thus, allows for student to respond to questions with graphs, equations, annotations, etc., making it particularly suited for use in STEM disciplines (arguably, it has a much wider usage profile). Here, the system was evaluated in two quite different contexts, namely a first year electronic engineering class in Maynooth University, Ireland and in two mathematic classes in The University of Queensland, Australia. In the former case, UniDoodle was used in the second half of each lecture to get the students to work through the material covered in the first half while, in the latter case, UniDoodle was used at the start of several lectures to revise material covered in the previous lectures.

The evaluation of UniDoodle focused on three aspects – usability, engagement and learning. Feedback obtained showed that the majority of students who used the system found it easy to use and did not encounter any technological issues. They found that the system improved interaction and engagement within the classroom and a large number of the students felt that the use of UniDoodle helped improve their learning. Feedback from the lecturer echoed these sentiments. They found UniDoodle relatively intuitive to use from their perspective and, more importantly, felt that it allowed both them and their students to receive significantly more useful feedback compared to other similar available student response systems. In general, there was overwhelming support for the use of UniDoodle with both students and lecturers calling for its continued use in class.

Acknowledgement

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