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# Introducing Electronic Voting Systems into the teaching of Mathematics

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## Introduction

Across university campuses in the UK and elsewhere around the world, academic staff share similar concerns about the nature of contemporary student teaching and learning. These concerns include the fact that class sizes are larger, students may appear unmotivated in class and student passivity is perceived to be high. The larger class sizes have made it easier for students to become 'anonymous', and it is a challenge for shy students to participate in class by, for instance, responding verbally to a question.

At Loughborough University, there has been a university-wide initiative to make lectures more interactive and get students more engaged by, amongst other things, introducing electronic voting systems (EVS) into lectures. Three staff from the Mathematics Education Centre (MEC), who mainly teach Engineering Mathematics to undergraduate students, have incorporated the use of EVS into their lectures. One of the authors of this paper (Robinson) has used EVS extensively in lectures over two academic years. The other author (King) is a PhD student whose research is to investigate the effectiveness of electronic voting systems in the learning and teaching of Mathematics in Higher Education. This article is a case study focussing on staff and student perceptions of EVS use in teaching Engineering Mathematics at Loughborough University.

## The technology

EVS is a technology that affords a lecturer the means to give students, especially in a large class, the chance to engage with course material by having them answer questions in class - with immediate feedback provided. The EVS system being used by Loughborough University is TurningPoint [1]. Its enabling software is embedded in Microsoft PowerPoint. So a lecturer can prepare multiple choice questions (MCQs) as a series of PowerPoint slides for, for example, formative assessment purposes. The students respond by clicking the corresponding alphanumeric answer choice on their EVS handsets (Figure 1).

**Fig 1 - Students using TurningPoint (EVS) handsets to register their responses to a question in class. Used with permission of Turning Technologies**

Student responses are then displayed on the PowerPoint slide in the form of a suitable chart (Figure 2). The lecturer may then decide to elaborate on any relevant issues arising out of the question and answer display session. For instance, a lecturer could address why options (a) and (d) in Figure 2, which 47% of the students in a class had selected as the correct option, are in fact incorrect.

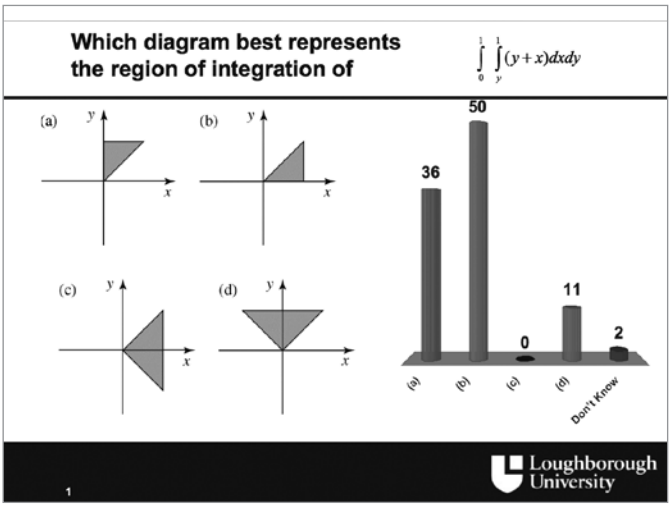


**Fig 2 - Slide showing student response to a question on double integration. Option (b) is the correct response.**

At Loughborough University students collect handsets at the beginning of a lecture where handsets will be used, and then return the handsets at the conclusion of the lecture. In the US (e.g. Purdue University and the University of Arizona), it is more common for students to purchase their own handsets at the beginning of a semester, so each student has a personal handset.

## Some relevant literature

Some of the earliest reports of EVS use in classrooms include those of Cue [2], and Hake [3]. The single, most important benefit of EVS use, identified from literature review, is its capacity to enhance, catalyse or increase student engagement during lectures. EVS is often used together with associated pedagogic applications like Peer Instruction (Mazur, [4]) and Just-in-time Teaching (Novak et al., [5]).

Caldwell's [6] review of existing literature on handset use is a comprehensive and detailed work that covers every aspect of handset use including description of the technology, use of questions, effect on student performance and association of handsets with 'peer learning'. The study also includes guidelines for writing good questions and best practice tips. Caldwell however claims that "…much research remains to be done to elucidate the reasons why handsets are effective" and also that "…the research so far is not systematic enough to permit scientific conclusions about what causes the benefits".

A very helpful book is that edited by Banks [7]. It provides some historical context, followed by practical cases in a variety of subjects, with associated discussions of the pedagogy associated with them, and finally outlines some of the directions that EVS may take in the future.

Papers with specific focus on the use of EVS in Mathematics include McCabe, Heal & White [8], Lomen and Robinson [9], and Cline, Zullo and Parker [10]. A more comprehensive overview of 10 publications on the use of EVS in Mathematics and Statistics can be found in Retkute [11]. Links to some resources and information about current users of EVS in Mathematics and Statistics can be found in the electronic repository of Retkute [12]. This latter work is funded by the MSOR network.

Further electronic resources with comprehensive information on the use of EVS include the repository created by Draper [13] of Glasgow University.

## The staff viewpoint

### The first year of implementation

During the first year of implementation, a blog was created by MEC staff for them to 'journal' their thoughts and experiences about the use of the technologies that had just been introduced into Engineering Mathematics lectures for the 2007/2008 session. In addition to this, observations, informal feedback, questionnaires and interviews were used to elicit staff perceptions of EVS. A detailed analysis of MEC (and other) staff perceptions of EVS, throughout the first year of usage, can be found in King et al. [14]. Some of the key findings are summarised below. These are followed by a personal reflection by one of the authors (Robinson) of the second year of implementation of EVS.

During the 2007/8 academic year, staff struggled initially with the increased preparation time associated with creating MCQs and learning how to use the TP software in order to use EVS in class. The preparation time however tended to decrease with time and staff's confidence levels in using EVS increased. One member of staff noted that it was a challenge to cover lecture material in classes where EVS was used. This was due to a number of factors including the number of MCQs used (using more questions reduces the time available for a lecture); the difficulty level of an MCQ – tougher questions take longer to solve; student response time allocation; and equipment setting up and closing down time.

The key benefit of EVS use that staff identified was that it has helped them to identify the topics or areas that students find challenging and to find this out during the lecture phase of an academic semester, not waiting until the examination phase at the end of the semester. For example, one of the participants was surprised to discover, via EVS feedback, that students were struggling with material the lecturer had assumed they would find easy to understand. The effective use of EVS provides staff with the knowledge of what needs to be corrected

and what needs to be reinforced in student learning (Russell [15]). Staff who do not have 'a sense' of how much students know or a means of gauging, week by week, student assimilation of the material they have been taught in class, cannot correspondingly make the necessary pedagogical changes in order to address identified gaps in students' understanding. Another very important benefit identified was that of increased student participation and contribution levels.

In addition to identifying key benefits the following were identified by staff as key requirements for maximising the effective use of EVS in Lectures:

- Creation of a bank of relevant, subject-specific EVS questions
- The selection and use of good questions which should include appropriate distractors
- Allocation of adequate time for student response and/or subsequent discussion
- Need to use EVS for stimulating thought and reflection and not just to test memory
- Not overusing the technology
- Creation of a university–wide support forum for sharing tips and ideas on how to use EVS glitch-free and effectively

**The second (current) year of implementation**

During the second year of usage, one of the authors (Robinson) obtained an Academic Practice Award from Loughborough University and this has enabled her to visit experts in the use of EVS and to set up a university-wide-support forum. The forum is proving popular with staff from departments across campus. It is not intended to be a forum for training staff in how to use EVS. Instead pedagogical considerations are much more to the fore. What questions are used for, how they are used, when they are used and the quality of the questions used are important considerations.

One of the experts visited was Professor David Lomen of the University of Arizona. David has authored books on Calculus (see for example Hughes-Hallett et al. [16]) and there are associated publications with questions (ConcepTests) for use with EVS. One of the outcomes of this visit was that questions used in 2007/8 with EVS were re-evaluated and, where possible, questions which tested concepts rather than just application of a technique were introduced. An example of this can be seen in Figures 3 and 4. Figure 3 asks students to calculate the gradient of a scalar function and was used in 2007/8. An additional question, Figure 4, was introduced in 2008/9 to test students' grasp of combinations of the grad, div and curl operators.

(The interested reader may wish to investigate the resources available under the Good Questions Project at Cornell University [17].)

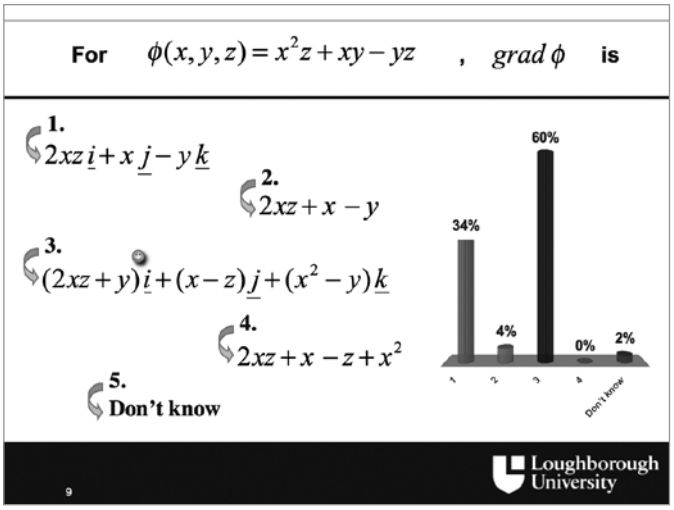


**Fig 3 – Example of a straightforward question on gradient of a scalar function.**

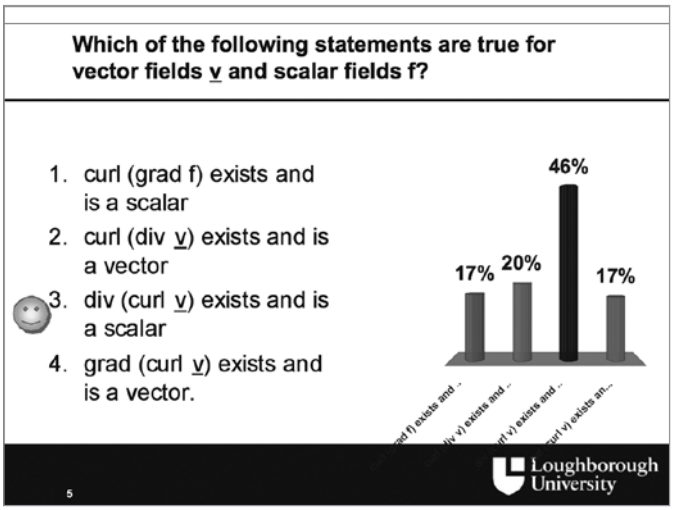


**Fig 4 – Example of a more demanding question on Vector Calculus**

The second year of implementation in Engineering Mathematics classes has focussed much more on the impact of EVS use on the teaching and learning process. A detailed evaluation is currently taking place and involves focus groups and interviews with staff and students.

## The student viewpoint

**The first year of implementation - students**

During the academic year 2007/8, 145 undergraduate students drawn from the Automotive, Aeronautical and Mechanical Engineering departments and who were in their second year of study participated in a study. The 145 students (from a total of 250 students who were taught using EVS) completed a questionnaire on the use of EVS. More details can be found in King and Robinson [18]. A few of the main findings are presented below.

In response to a question on how useful students found EVS, 80% of students said they found EVS 'useful' or 'very useful'. 15% were neutral and 5% found EVS either 'not at all useful' or 'not very useful'.

To determine which attributes of handset use students found the most beneficial, students were given a list of

| Position | Benefits |
|---|---|
| 1st (most important) | Checks whether I'm understanding course material as I thought I was |
| 2nd | Allow learners to identify problem areas |
| 3rd | It makes lectures more interactive |
| 4th | Makes me think more about the course material during lectures |
| 5th | Gives me an idea of how well everyone else is doing |
| 6th | Allows me to answer privately without others knowing how I voted |
| 7th | It's fun |

**Table 1 - Benefits of EVS - ranked by students**

seven benefits on the questionnaire and asked to rank the three benefits that they considered the most important, in order. The results of this are shown in Table 1.

The top two benefits identified from the ranking exercise point to the very important role that handsets play in providing feedback to students. In fact Nicol and Macfarlane-Dick [19] note that the formative feedback that the use of EVS engenders is pivotal in the learning process.

Other benefits identified by students are provided in the following quotes:

- **Anonymity:** "If you get it wrong no one knows you're stupid"
- **Problem identification:** "Allows lecturer to know if students are understanding material and hence what to re-cover"
- **Engagement/Interactivity:** "Keeps people awake and attentive during lectures";
- **Participation:** "Gets you involved with the lecture"; "Your [i.e. you are] not afraid to give an answer."

Responses to a questionnaire item on the perceived disadvantages of handset use shows that two main drawbacks were identified – EVS sometimes do not work (78 students) and it takes time to set up the systems for use in class (42 students). These drawbacks have to do with setup and operational issues which can be more readily overcome as staff competence and confidence in using EVS increase with time.

*"Student submissions show that the use of Electronic Voting Systems predisposes 85% of all students towards answering questions in class, compared to 29% when students are asked to respond by raising their hands or 13% when they are asked for a verbal response."*

To evaluate whether handset use had significant advantages over other methods that are usually used to solicit student response in class, students were asked to specify how likely they were to respond when handsets are used compared to raising of hands or giving a verbal response. Student submissions show that the use of EVS predisposes 85% of all students towards answering questions in class, compared to 29% when students are asked to respond by raising their hands or 13% when they are asked for a verbal response.

One of the questions in the study was to investigate whether students think it is appropriate for Mathematics to be taught using EVS. Some students, in open feedback, had given responses such as "Some questions are pointless"; "Lecturer sometimes just asks questions instead of teaching it [the topic]" – suggesting that Mathematics may not be a suitable medium for EVS use. However, the overwhelmingly positive response – 88% of students indicated that they consider EVS 'appropriate' for teaching Mathematics – seems a clear verdict that students welcome the use of handsets to teach Mathematics.

### The second year of implementation - students

In the academic year 2008/9 staff are, of course, teaching using EVS with a new group of students. To ascertain more about the learning experience taking place in classes where EVS is being used, some students are being invited to take part in focus groups and interviews. Questions used in class are presented again to the students and they are asked to reflect on the learning process as different questions are presented. This work is still in its early stages and will be reported upon in due course.

## Conclusions and Future Work

This article reports the perceptions of staff in the MEC at Loughborough University who are in their second year of using EVS to teach Engineering Mathematics. Students' viewpoints on the use of EVS in 2007/8 are also presented. In the first year the focus of staff was very much on learning to use the technology. In the second year there is much more emphasis on the designing of questions to ensure that EVS impact on student learning and achievement. Pedagogical considerations are much more to the fore.

In the first year, 80% of students reported that they found the handsets useful and identified many benefits associated

with their use, most importantly the feedback provided to them regarding their understanding of the course material. The results also show that compared to standard student response solicitation methods, EVS use promotes higher student in-class participation rates. The 2008/9 cohort of students are being asked to take part in focus groups and interviews to ascertain more about the learning experience taking place when EVS are used.

Future study will also seek to measure the impact or influence of EVS use (if any) on student performance.

The authors would be very pleased to hear from other colleagues using EVS to teach Mathematics or Statistics.

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