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Exploring Technology-Based Continuous Assessment via Electronic Voting Systems in Mathematics and Statistics

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Introduction

The use of technology to enhance the teaching and learning experience is increasing in Higher Education institutions. As assessment is an integral part of learning, we are interested in the possibility of technology-based continuous assessment in mathematical education. Electronic Voting Systems (EVS) are a type of interactional technology that allows students to turn inherited passivity into dynamic interaction.

Background

An EVS system usually consists of a computer (laptop), projector, one or more receivers, and a handset unit called a *clicker* for each student. Clickers are remote-control handheld electronic transmitters making use of either infrared or radio frequency information transfer (see Fig 1). A review of currently available systems and an evaluation of their benefits and drawbacks can be found in [1]. The system can be set up for a single one-off session or established as a permanent installation in a classroom or lecture theatre.

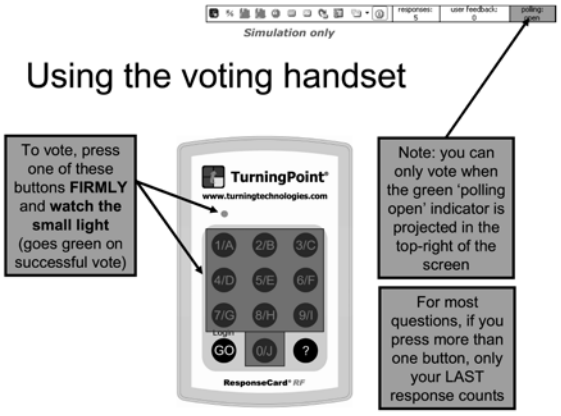

Fig 1 – A typical handset together with instructions for use.

Interaction in a lecture is achieved by a feedback loop in which a question is asked or an issue raised. Questions are displayed to students by embedding them within PowerPoint slides. Once a multiple-choice question is asked, use of clickers allows students to select their preferred option for the answer. The handsets transmit this information to a receiver, which in turn transmits it to the voting software on a computer. After an allocated time, chosen by the lecturer, the software produces and displays a histogram or bar chart of the results and the lecturer then chooses a course of action to respond to the results. If the questions are used primarily to test students' understanding of material covered recently, a low proportion of correct answers allows the lecturer to identify problematic areas and immediately initiate discussion or revisit topics where there is evidence of misconception. Voting can be used as a way of introducing and stimulating interest in a new topic, or to test how much students

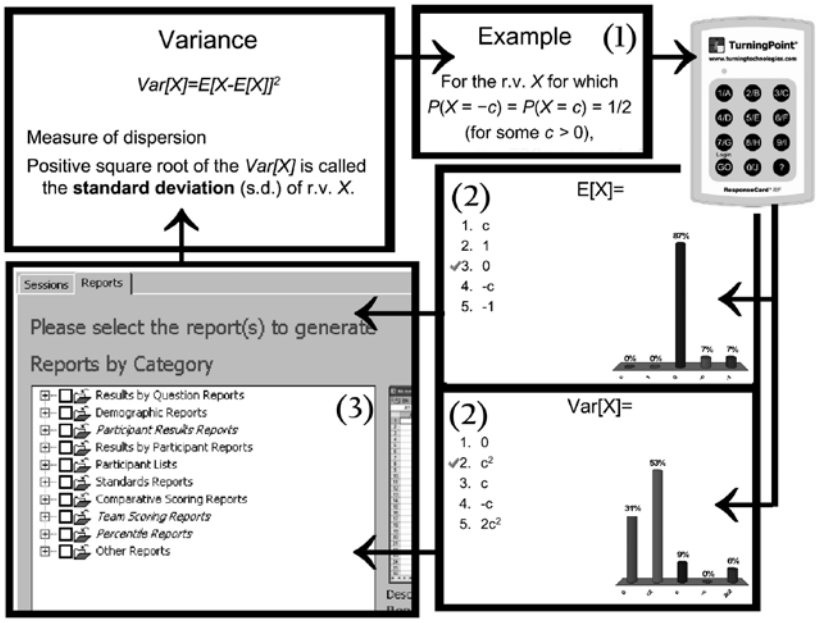

Fig 2 – Workflow of EVS session: conventional lectures are combined with interactive sessions by (1) presentation of a multiple-choice question, (2) gathering of student responses rapidly and anonymously, (3) monitoring students' understanding.

had remembered about a topic from their previous lectures. The computer keeps a record of the numbered handsets' responses allowing the results to be analysed later. An example of an EVS session is shown in Fig 2.

Pedagogy behind EVS

In the past decade interest in using more active methods to enhance the learning of sciences has grown and the use of clickers has been researched both from the point of view of practical implementation [2,3] and the pedagogy associated with applications [4,5]. Physics education researchers have developed a variety of methods that make use of various voting sets which have been shown to produce measurable learning gains when used to promote active learning [5-7]. The benefits include increased motivation and interaction, incorporation of rapid feedback, progress of understanding during lectures and adaptation of the lecture material in response to formative assessment.

A study of 6,000 students, taking introductory physics courses, taught with traditional methods versus interactive assessment methods concluded that interactive methods enhanced problem-solving ability [8]. When examining the transformation of courses from passive to active learning experiences it is important to use controlled experiments. Study of the individual response data per student over the course of a single semester suggested that the level of involvement during the class is positively correlated with better learning outcomes [9]. Furthermore, a controlled study examining the relationship between personality and attitude towards EVS indicated that more positive ratings of EVS have been obtained from students who are more extrovert and conscientious [10]. Students who earn higher grades also show higher appreciation of interactive methods compared to other students.

Using EVS in Mathematics and Statistics

The number of published reports on the use of clickers in the field of mathematical education is much smaller than the number in physics education. Eleven publications [11-21] on applications of Electronic Voting Systems in mathematical or statistical teaching are reviewed in Tables 1-3. The content of each paper was analysed to identify three aspects: the context in which voting systems are used (module and class size), pedagogical practice, and student perceptions. Electronic Voting Systems were used in large groups with class sizes of more than 100 students, as well as in smaller groups with class sizes of less than 50 students. When looking at the pedagogical practices, two important factors in using EVS are the design of the multiple-choice questions used

Publication	Module	Class Size
Wit 2003 [11]	Statistics	210
D'Inverno, Davis and White 2003 [12]	Engineering Mathematics	200
Stuart, Brown and Draper 2004 [13]	Logic	140
McCabe and Heal 2006 [14]	Discrete Mathematics	NA
Miller, Santana-Vega and Terrell 2006 [15]	Calculus	15-26
Butler and Butler 2006 [16]	Liberal Arts Math	200
Blodgett 2006 [17]	Algebra	40
Cline, Zullo and Parker 2007 [18]	Calculus, multivariable Calculus, Differential Equations and Linear Algebra	20-25
Lass, Morzuch and Rogers 2007 [19]	Introductory Statistics	200
Lucas 2009 [20]	Calculus II	24
Robinson and King 2009 [21]	Engineering Mathematics	250

Table 1 – Case studies on the use of EVS

Wit 2003	EVS was used in a one-hour tutorial every two weeks. Multiple-choice questions were based on basic definitions and interpretations of formal analysis and sometimes contained trick questions. To accommodate a better learning process discussion between the students was encouraged after the first voting. If, after a second round of voting, the answer distribution got worse, the lecture either followed the route of traditional explanation or engaged students in a set of branching questions to explore the origins of the confusion. In some tutorials a 50:50 technique was used – half of the incorrect answers were eliminated before a second round of voting followed with explanations of why incorrect answers were wrong.
D'Inverno, Davis and White 2003	There were two lectures a week for 12 weeks, with the EVS session held at the end of each lecture. The use of EVS consisted of asking the students to answer multiple-choice questions without conferring.
Stuart, Brown and Draper 2004	The voting system was used in nine out of the twelve lectures. The lectures depended on preparation of examples that would be worked on in the lectures, but the questions were generated spontaneously. The lecturer occasionally asked individual students oral questions that required an open-ended answer and then asked the rest of the class to vote if they agreed or disagreed with that answer. More complex questions about how well the class felt they understood the material have been asked to provoke the redirection of presentation. For example, students had three possible choices to describe understanding of a specific topic: Press 1 for 'Dead easy', Press 2 for 'Difficult but I'm getting there', Press 3 for 'Dastardly'. In order to encourage student–student interaction, students were occasionally asked to answer a question without thinking about it for too long; then they had a discussion with their peers and had to vote again.
McCabe and Heal 2006	Initially, EVS was used during revision sessions at the end of a module, designed to help students prepare for the examination, identify their weaknesses and encourage revision. Students voted anonymously, discussed the solutions with their peers or the whole class and received feedback from the lecturer. Later, handsets were also used in smaller group tutorials.
Miller, Santana-Vega and Terrell 2006	There were 330 students enrolled in 17 small sections of 15-26 students, taught by 14 different instructors. Each instructor had the freedom to choose their teaching method, including the option to use a classroom voting system, and if so, how exactly to use it. The class met 4 days per week for 50 minutes with the instructor.
Butler and Butler 2006	The lecturer used the EVS throughout each lecture. Students were able to read the EVS questions before the start of the class as it was expected that students would work on them before the lecture. During every EVS session the lecturer selected how many points to offer for correct and incorrect answers. One way is to grade the session giving all students participating credit, regardless of the correctness of their answers. Also, a scheme where one point is awarded for an incorrect answer and two points for a correct answer was implemented. EVS points made up 10% of the students' final grade. The survey at the end of semester showed that students found fostering in-class discussion to be a positive aspect of EVS use and that EVS questions were helpful generally in preparing for examinations.
Blodgett 2006	Lecture materials included the use of interactive questions and sessions of EVS, where the handset was a two-way response unit. Students answered numerical, true-false, and multiple-choice questions, which were similar to problems in the textbook, and received immediate feedback via right/wrong lights on their handset. Students were encouraged to discuss their answers and solutions with their peers.
Cline, Zullo and Parker 2007	At the beginning of the semester, students purchase a numbered list of multiple-choice questions. Several times during each class, the lecturer chose a question and gave the students a few minutes to read the question and discuss it with their peers in small groups before registering their choice. The voting answer distribution was displayed. The lecturer could then go around the class, asking different students to explain which option they voted for and why.
Lass, Morzuch and Rogers 2007	EVS was used during 33 of the 42 lecture periods. The lecturer used voting at the beginning of lectures to address material that had been covered recently and also during the lecture. Multiple-choice questions varied from brief to more involved statements, depending on the topic. EVS questions accounted for 5% of the student's course grade.
Lucas 2009	The class met three times a week with the last 20 minutes dedicated to problem solving. The EVS cycle was divided into the "think" phase and "pair/share" phase. Multiple-choice questions were presented on a classroom screen. In the "think" phase, students were asked to input their selection and after a few minutes, the results of voting were shown on the screen. Students then formed small groups and during "pair/share" phase they discussed the question with their peers and re-voted. The lecturer then reviewed the question and answer with the class as a whole.
Robinson and King 2009	The EVS has been used extensively in every lecture. At the beginning of the lecture students collected handsets, and then returned the units at the end of the lecture. Multiple-choice questions were used to test students' understanding of techniques and concepts.

Table 2 – Pedagogical practice

and the incorporation of peer instruction. Different forms of question design can be used depending on the purpose of the EVS implementation. A question may be a simple Yes/No or True/False type; students may be asked to recognize solutions or an appropriate approach for solving a problem. Questions may also be broken up into smaller stages or be purposely ambiguous. Peer instruction is basically a discussion between students, in this case initiated during the lecture. After answering each question students are encouraged to discuss their answers and solutions with their neighbours [5]. A successful implementation of both these factors allows the lecturer and students to get the most out of Electronic Voting Systems.

Wit 2003	A clear improvement of attendance rates was observed. A study showed that 74% of students thought that the use of handsets had been useful in aiding their understanding of statistics and 79% saw more benefits than disadvantages in the use of EVS.
D'Inverno, Davis and White 2003	Results of a student survey indicated that the students found the system easy to use and 75% responded that they would recommend the use of clickers in other lectures. Some students saw the system as a waste of time. One of the drawbacks was that students found some questions were not always clear and sometimes involved typographical errors.
Stuart, Brown and Draper 2004	In informal interviews students indicated that they were more likely to try and work out the answer to a question if handsets were being used. End of semester evaluation showed that 77% of students rated EVS useful, very useful, or extremely useful.
McCabe and Heal 2006	A verbal feedback at the beginning of the semester and written evaluation at the end of the semester showed that students enjoyed EVS in classes and perceived them as beneficial to their learning. A controlled experiment was conducted and the improvements to the student examination results were significant and have been attributed to the use of EVS.
Miller, Santana-Vega and Terrell 2006	Instructors and students were questioned three times in the term to determine how frequently and in what ways electronic voting was used in class and after the examination the different sections were compared. It has been found that different ways of using mathematical thinking and reasoning affected student learning.
Butler and Butler 2006	Students have adjusted to the process of employing EVS easily and were particularly motivated to participate in EVS questions when they are allowed to work together and when part of the course grade depended on their answers.
Blodgett 2006	It has been found that the mean examination score of the treatment group was not statistically significantly higher than the mean examination score of the control group, although students showed an increase in interest and attentiveness in classes where EVS was used.
Cline, Zullo and Parker 2007	It has been observed that students liked the process of clicking in with their votes and were not intimidated by the participation in the post-vote discussions. Student focus groups indicated that they learned more from voting than from traditional lectures.
Lass, Morzuch and Rogers 2007	Use of EVS encouraged attendance and participation during classes, but there was no perceived impact on how students rated the course in relation to the previous year where no EVS was used. Students felt there to be a significant increase in the course workload. They had higher grade expectations and did indeed achieve significantly higher grades.
Lucas 2009	Students indicated that they appreciated the variation from lecturing, felt encouraged to become active participants and paid more attention during the lecture knowing that they would be tested at the end. Detailed study indicated that asking students to write down their solutions during a "think" phase and then encouraging them to engage in discussion had significantly improved their overall performance.
Robinson and King 2009	Results of a questionnaire on the use of EVS showed that 80% of students found EVS 'useful' or 'very useful' and 88% of students indicated that they consider EVS 'appropriate' for teaching mathematics. The feedback regarding students' understanding of the course material has been identified as the most beneficial attribute of EVS.

Table 3 - Student perceptions

Discussion

The results of the case studies discussed in [11-21] showed that students are comfortable using the Electronic Voting System, that they are positive in supporting technology-based continuous assessment and that they felt more involved in an active learning process. These studies suggest that better learning outcomes are really the result of changes in pedagogical focus, from passive to active learning, and not a consequence of the specific technology or technique used.

One-way input EVS is not the only technique for delivering interactive classroom communication – other possibilities include a response system which operates entirely online [22] and an audience response system which uses mobile phones and PDAs [3].

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