The association between students’ use of an electronic voting system and their learning outcomes

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Abstract
This paper reports on the use of an electronic voting system (EVS) in a first-year computing science subject. Previous investigations suggest that students’ use of an EVS would be positively associated with their learning outcomes. However, no research has established this relationship empirically. This study sought to establish whether there was an association between students’ use of an EVS over one semester and their performance in the subject’s assessment tasks. The results from two stages of analysis are broadly consistent in showing a positive association between EVS usage and learning outcomes for students who are, relative to their class, more correct in their EVS responses. Potential explanations for this finding are discussed as well as modifications and future directions of this program of research.

Keywords
electronic voting system, engagement, interactivity, lectures

Implementations of electronic voting systems
The use of electronic voting systems (EVSs) in higher education is becoming more widespread. EVSs typically comprise four primary elements: a tool for presenting lecture content and questions (e.g. a computer, presentation software such as MS PowerPoint and a digital projector), electronic handsets – akin to a remote control – that enable students to ‘respond’ to a lecturer’s question, receivers that capture students’ individual responses and EVS software that collates and presents students’ responses. With an EVS in place, every student in a class can respond to multiple-choice questions set by the lecturer. Students use their handset to transmit a response, via a receiver to a central computer, which collates all responses and displays them to the group, typically in the form of a bar chart.

The way in which EVSs have been used in learning contexts varies as does the pedagogical rationale associated with their use. Lecturers have used EVSs in their teaching without radically changing the traditional lecture format. With this method, standard lectures are supplemented with questions, and students’ responses provide feedback to both students and staff on the learning process. This type of EVS implementation – reported for logic, computing science and economics lectures – provides an opportunity to adapt the traditional lecture format dynamically. (Elliott 2003; Draper & Brown 2004; Stewart et al. 2004).

A second way in which EVSs have been used is exemplified by Wit (2003) who used an EVS specifically as a diagnostic tool in large group tutorials. Wit (2003) asked students questions about the material covered in earlier traditional teaching sessions, which
allowed him to quickly determine and then address the precise nature of their misunderstandings. When an EVS is used in this way, topics covered in the EVS sessions are directed by students’ responses.

EVSs have also been used as a tool to support exam preparation (see Irving et al. 2000; Draper & Brown 2004). In this scenario, students are presented with questions akin to those they would expect in formal assessment. A discussion led by the lecturer follows students’ responses in an attempt to clarify difficulties that students may have had either with the structure or content of the question.

In a popular and more radical use of EVSs, independently pioneered by Mazur (1997) and Dufresne et al. (1996), the standard lecture format is heavily revised when an EVS is adopted (see also Burnstein & Lederman 2001; Boyle & Nicol 2003; Nicol & Boyle 2003). The two most common implementations in this area rely heavily on peer-based discussion within the classroom and are labelled ‘Peer Instruction’ (Mazur 1997) and ‘Class-wide Discussion’ (Dufresne et al. 1996).

With Peer Instruction, students are required to complete preparatory work prior to the teaching session and the session itself revolves around EVS questions. These questions probe students’ understanding of the fundamental concepts underlying their preparatory work and the discipline more generally. Once students have responded individually to a lecturer’s question and the class responses have been displayed, students enter a discussion mode with one or two of their peers. During this time, students discuss alternative points of view on the question and attempt to reconcile any differences in their responses. A second individual vote follows, which allows the class to assess how viewpoints have changed and the lecturer to determine whether further discussion or interventions are required.

Class-wide Discussion is similar to Peer Instruction but, as the name suggests, places less emphasis on small peer-based interactions. After discussing a lecturer’s question with their peers, students respond either individually or as a group, using the EVS. After the class responses are collated and presented, the teacher leads a class-wide discussion on issues that have emerged in the students’ responses. Typically, the lecturer will come to some resolution of the question after this discussion, providing feedback on the alternative responses and explaining which are most appropriate.

**How can EVSs assist students’ learning?**

Researchers have primarily suggested two ways in which the use of an EVS can directly assist students’ learning: through active learning and the provision of feedback. A criticism of large group lectures is that they reduce students’ involvement in learning to that of a passive bystander. Many authors have argued that the ability of students to respond anonymously with an EVS reduces the response reticence typically found in large classes (Cue 1998; Draper et al. 2001; Jones et al. 2001; Elliott 2003). Increasing the likelihood of students responding is seen as beneficial because, in doing so, they become active participants in the lecture and learning processes associated with it.

Researchers have discussed two interrelated mechanisms to account for how active participation through EVSs supports students’ learning. Draper et al. (2001) suggest that during the formulation of their answer to an EVS question, students are required to engage in a level of cognitive processing or reprocessing of the lecture or course material, or as they put it, ‘rebuilding it on their own personal mental foundations’ (p. 164). This increased processing should be beneficial and ultimately result in greater understanding of the material that is presented. Alternatively, authors such as Dufresne et al. (1996), Mazur (1997) and Nicol and Boyle (2003), whose implementations of EVSs emphasise peer-based discussion, suggest that the activity of discussion associated with the EVS supports learning. During their interactions, students must articulate the reasoning behind their answers, reflect on the reasoning of others and evaluate the validity of each explanation. These activities benefit students by helping them reflect on and organise the principal concepts underlying the subject.

Clearly, there is overlap between these two perspectives on active learning in EVS-enabled lectures. Ultimately, both are suggesting that in EVS-enabled lectures, students are required to engage cognitively with the concepts presented to a greater degree – either by reflecting on and responding to a question or through peer-based discussion associated with developing and/or reflecting on a response. While Dufresne...
et al. (1996) say ‘there is no clear evidence that [a student’s] commitment to a particular response has significance for learning’, they do suggest that participating in EVS-enabled lectures involves students in some kind of cognitive processing. Like Draper et al. (2001), they suggest that posing questions to students requires them to process lecture material, primarily through the use of the learning strategies of organisation and elaboration (see Weinstein & Mayer 1986). In Dufresne et al.’s (1996) words, students are required ‘to pull ideas from various prior experiences (e.g. readings, lectures, other courses, previous class-wide discussions, or personal observations)’ (p. 15).

The provision of feedback is the second commonly stated benefit of EVS-enabled lectures. Students’ responses to questions provide important feedback to both lecturers and students. An EVS can be used as a formative assessment tool in lectures, whereby students can test their knowledge of the concepts being presented in an anonymous and risk-free manner. Lecturers can use EVS responses to gather feedback about their students’ current understandings. The diagnostic nature of students’ responses provides lecturers with an opportunity to adjust the flow and focus of their lecture presentation. They may return to previously covered material, skip over unnecessary material or attempt to address major student misconceptions explicitly. This ability to adapt lectures based on students’ feedback is seen by many as a clear advantage of EVSs (Dufresne et al. 1996; Cue 1998; Draper et al. 2001; Elliott 2003) and is epitomised by Draper and Brown’s (2004) notion of ‘contingent teaching’, where the lecturer’s presentation is largely, if not entirely, driven by the answers provided by the students.

It is apparent that the two proposed benefits of EVS outlined above – active learning and the provision of feedback – provide a clear rationale for suggesting that students’ use of an EVS would be associated with beneficial learning outcomes. This question was the focus of the empirical investigation reported in this paper.

**Empirical investigations of EVSs**

Most evaluations of EVSs reported in the literature are based on interview and questionnaire data gathered from students and teaching staff and are generally supportive of the technology. Many of these evaluations have considered students’ affect, their levels of interest and their motivation to attend EVS-enhanced lectures. For example, Cue (1998) and Elliott (2003) reported that using EVSs increased lecture attendance, while Boyle and Nicol (2003) reported that attendance at sessions using an EVS was always above 80%, significantly higher than for the previous years’ sessions that did not use an EVS. Finally, students in a number of studies have reported that seeing the collated responses of other students increases their interest in the lecture (Cue 1998; Draper & Brown 2004).

A regular finding of evaluations of EVS implementations is that regular feedback is provided to both students and staff on the learning process. For example, Elliott (2003) reported that students found that the class-wide presentation of students’ EVS responses was beneficial in enabling students to gauge their level of understanding. Draper and Brown (2004) reported on the use of EVSs in eight departments across one institution over a 2-year period and from this review they reported that the communication between teachers and learners was enhanced. Students in large classes responded to questions, and the anonymous nature of EVS responses was widely reported by students as the primary reason for their engagement. Interestingly, tutors in EVS-supported seminars reported that quiet students responded using the technology but were still reluctant to speak out (Jones et al. 2001), a finding mirrored in the large group tutorials (Wit 2003).

In their review article, Draper and Brown (2004) also reported on the degree to which an EVS encourages students to think in lectures. They found that students who used an EVS over a semester in a single course reported that they were twice as likely to attempt to construct an answer to a question posed using an EVS compared with a question that required them to respond verbally or by putting up their hand. In a similar vein, Elliott (2003) reported that the use of an EVS raises students’ concentration level while Pickford and Clothier (2003) found that both staff and students thought that the classes that used a voting system engaged the whole group in thinking and answering. Finally, Boyle and Nicol (2003) reported that students thought their memory retention had improved through the use of an EVS, although no empirical evidence was reported to support this.
Crouch and Mazur (2001) and Dufresne et al. (1996) are among the few researchers to have carried out experimental investigations of EVSs based on standardised tests (Hestenes et al. 1992; Hestenes & Wells 1992). In the area of Physics education, these researchers found that over a semester, students in EVS-enabled lectures showed greater learning gains than students in more traditional non-EVS-enabled lectures. It is not clear whether this change was predominantly a result of the altered teaching and learning method – both implementations involved a radical shift in this regard – or the introduction of the EVS technology. It is clear, however, that a change away from more traditional teaching and learning methods was beneficial to students (see Hake 1998).

In summary, there is clear research and evaluation evidence supporting the contention that EVSs improve students’ learning experience in large group lectures. In particular, there are widespread reports of EVSs having a positive effect on students’ concentration, enjoyment and attendance. EVSs have been found to support communication between students themselves and between students and lecturers. There has been some support for the notion that EVSs encourage students to ‘think more’ about the content of their lectures; that is, they encourage students to reflect and process course material more fully or deeply. Consistent with this, some research has suggested that EVS-enhanced lectures lead to greater student understanding when compared with more traditional lecturing approaches.

Despite this research evidence, Elliott (2003) and Boyle and Nicol (2003) note that many investigations of EVS use are based on self-report and qualitative methodologies. While not inherently problematic, these authors suggest that evaluations that assess each individual student’s use of the EVS would be useful in order to better understand an EVS’s effectiveness. No studies of this nature are reported in the literature. Given this, the primary aim of the investigation reported in this paper was to determine whether an association existed between students’ use of an EVS and their learning outcomes. Based on our review of how the use of EVSs can support student learning, and previous evaluations, we expected that students’ use of an EVS would be associated with a greater understanding of the course material, reflected in superior performance in course-based assessment.

**Method**

**Participants**

Participants in this investigation were students enrolled in first-year computer science at the University of Glasgow in 2002. As part of their first-year studies in computer science, students complete a year-long subject on introductory programming (CS1P). While 330 students enrolled in CS1P in 2002, a full complement of data was only obtained from a subset of these students (n = 241). As the EVS was only used in the first semester of CS1P, only students who had used the EVS to some extent across this semester, and had undergone both the end-of-semester and end-of-year assessments, were included in the current study.

**Context of use – EVS implementation**

The lecturer’s motivation for using an EVS was principally to provide students with the opportunity to engage with the new content material of a lecture, to allow them to apply the content of lectures to practical programming problems and to provide an alternative feedback mechanism to students on their understanding of the course content. An EVS was implemented in the first semester of a traditional year-long lecture course, which comprised 24 lectures over 12 weeks. The EVS was used in 13 lectures, and in each of these sessions, students were asked between two and six questions. The 13 EVS-enabled lectures came predominantly in the middle of the semester, after orientation to the course and before course summary lectures began. The format of lectures was not altered markedly to accommodate the introduction of the EVS. Typically, the lecturer stopped his presentation at preordained points in the content to pose a question to students. Students were given time to respond (approximately 2 min) and, while they were encouraged to discuss their potential responses ‘with their neighbour’, peer-based discussion was not a major component of the EVS implementation. When all (or a vast majority) of responses had been received, the lecturer displayed a histogram of students’ collated responses. At this point, the lecturer used the class responses as an impetus to discuss the concepts and principles inherent in the question. Students were provided with feedback on their responses and both correct and incorrect responses were explained to
students where appropriate. Often the lecturer led class-wide discussions where students were asked about their responses, but rarely were students given the opportunity to respond to an EVS question for a second time.

Data collection and measures

Students were assigned an EVS handset at the start of the semester and response data were automatically recorded during the first semester of CS1P. After each session, the data associated with the questions asked, individual students’ responses and the time taken to respond were stored in a spreadsheet. Students’ responses were accumulated over the first semester and were matched to their responses on the other measures using handset identification and matriculation numbers. Given that the course contained repeat lectures (i.e. a 12.00 lecture was followed by a 1.00 lecture to a smaller group of students), students’ responses were aggregated across these two sessions.1

A total of 33 questions were asked in lectures across the semester. While all questions used a multiple-choice format, two different types of questions were used. Nine questions asked students about their general study attitudes and behaviour (e.g. ‘When will you start preparing for the Practical Class?’). The second type of question (n = 24) asked students specifically about the course content. There were two types of ‘Content’ questions: those with definitive answers (n = 16) and those without (n = 8). An example of the former is ‘Is this activity sequential, repetitive or conditional?’ and the latter is ‘Which of the following solutions is best?’ (where there are sound arguments for more than one correct response). Only questions related to the content of lectures were used in this investigation.

Performance was measured using two assessment tests used in the Department of Computing Science. The first measure was the end-of-semester test (Class Test), which students were required to take at the end of first semester and counted 10% towards students’ final mark. The second measure was students’ final exam mark, which accounted for 70% of students’ final mark in CS-1P. This exam assessed first- and second-semester material and was conducted at the end of the year.

Results

Two indices associated with EVS usage were created. A Content Response index of usage was calculated by summing the number of responses that each student gave to the 24 questions on the content of lectures ($M = 14.73; SD = 5.67$). A second index, Correct Response, was created to give an indication of the proportion of questions that students answered correctly. This index was calculated by dividing the number of correct answers by the number of correct/incorrect questions attempted ($M = 0.30; SD = 0.18$). Measures of performance were based on the end-of-semester Class Test ($M = 63.51; SD = 18.06$) and the end-of-year Exam ($M = 54.91; SD = 19.45$).

In order to determine whether different student usage patterns existed for the response indices, a cluster analysis was first performed on the two response variables. A dissimilarity matrix was constructed using these new variables (using the squared Euclidean distance similarity measure). The dissimilarity matrix was used in a cluster analysis (Ward’s method) to determine whether distinct clusters would emerge. The dendrogram resulting from this analysis showed four clear groups.

There were significant differences between these clusters on both response indices ($F(6, 470) = 172.73; P < 0.001$). The mean scores for Content Response and Correct Response indices for the resultant clusters are presented in Table 1. It can be seen that students in Cluster 1 are low EVS users, who get a moderate number of their responses correct. Students in Cluster 2 are high EVS users, who get a low number of their responses correct. Students in Cluster 3 both use the EVS to a low extent and perform poorly when they use it. Finally, students in Cluster 4 use the EVS to a great extent and are similar to students in Cluster 1 in that they get a moderate number of their responses right.

The four clusters were used as an independent variable in a one-way MANOVA where Class Test and Exam were used as the dependent variables. A significant multivariate effect was recorded ($F(6, 470) = 4.01; P = 0.001$). The univariate tests indicated that there was a significant difference between clusters

1There were only five instances where students responded with the EVS in both lectures. In these instances, the first response was recorded in the data set and the second response was discarded.
scores across the thirteen lectures established a lecture attendance index. An aggregate of responses. Students were regarded as attending a lecture if they recorded students. were seen as impractical with classes regularly comprising over 300

Table 1. Mean scores for Content and Correct Response indices for four clusters

<table>
<thead>
<tr>
<th>Cluster</th>
<th>N</th>
<th>Content Response</th>
<th>Correct Response</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>M (SE)</td>
<td>M (SE)</td>
</tr>
<tr>
<td>Cluster 1</td>
<td>35</td>
<td>9.69 (0.49)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.55 (0.02)&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Cluster 2</td>
<td>108</td>
<td>18.31 (0.28)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.23 (0.01)&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Cluster 3</td>
<td>61</td>
<td>8.79 (0.37)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.16 (0.01)&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Cluster 4</td>
<td>35</td>
<td>19.89 (0.49)&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.49 (0.02)&lt;sup&gt;c&lt;/sup&gt;</td>
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Different superscripts within columns indicate significant differences.

on both the Class Test ($F(3, 235) = 7.11; P < 0.001$) and the Exam ($F(3, 235) = 7.30; P < 0.001$). The mean scores for each Cluster on Class Test and Exam are presented in Table 2. It can be seen that students in Cluster 4 (high users who were moderately successful) were performing significantly better than other groups on both the Class Test and the Exam.

While the results presented in Tables 1 and 2 suggest that neither EVS use nor ability alone can account for variations in students’ learning outcomes, it is clear that a number of students were regularly not using the EVS to respond to the questions posed by the lecturer (Clusters 1 and 3). One possible reason for low EVS usage is that some students were absent from a significant number of lectures. Given this possibility, we were keen to investigate whether attendance was an important factor in explaining the variance in students’ performance. As attendance data were not collected as part of this investigation, we were unable to conduct analyses using this variable. In order to investigate the impact of attendance, additional analyses were conducted with a subset of the original sample of students. Further analyses were restricted to those students who consistently attended lectures in order to minimise the variation in lecture attendance within the sub-sample. Students who were present at more than 10 of the 13 EVS-enabled lectures (over 75% of lectures) were sequestered from the original sample ($n = 96$).

<table>
<thead>
<tr>
<th>Cluster</th>
<th>Class Test</th>
<th>Exam</th>
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<tbody>
<tr>
<td></td>
<td>M (SE)</td>
<td>M (SE)</td>
</tr>
<tr>
<td>Cluster 1</td>
<td>64.34 (2.94)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>55.14 (3.17)&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Cluster 2</td>
<td>61.25 (1.67)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>53.28 (1.80)&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Cluster 3</td>
<td>60.03 (2.29)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>49.82 (2.40)&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Cluster 4</td>
<td>75.63 (3.17)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>67.80 (3.17)&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Different superscripts within columns indicate significant differences.

The analyses carried out with the full sample were replicated with these regular lecture attenders. Thus, a cluster analysis using Content and Correct Responses was conducted which used squared Euclidean distance as the similarity measure and Ward’s clustering method. The dendrogram suggested a three-cluster solution was appropriate and multivariate tests showed that the three clusters were discriminated by both measures ($F(4, 186) = 59.02; P < 0.001$). Table 3 shows that students in Cluster 1 were similar to those in Cluster 2 in terms of frequency of response. Students in these clusters were very high responders and responded significantly more than students in Cluster 3. However, students in Clusters 1 and 3 showed similar responses when it came to Correct Response. Students in these clusters were getting answers incorrect more often than students in Cluster 2.

These three clusters were used in a final analysis where Class Test and Exam were used as dependent variables. A significant multivariate effect was recorded ($F(4, 186) = 5.49; P < 0.001$), and univariate tests were significant both for Class Test ($F(2, 93) = 8.54; P < 0.001$) and Exam ($F(2, 93) = 7.69; P = 0.001$). Planned contrasts were used to compare the three clusters, the results of which are shown in Table 4. It can be seen that students in Cluster 2 (high responders who were getting more answers correct) were doing significantly better than students in Cluster 1 (high responders who were getting fewer answers correct). While students in Cluster 3 (low responders who were getting fewer answers correct) achieved results that were similar to students in Cluster 1, perhaps surprisingly their results in the class test were not significantly different from those in Cluster 2 (despite being different by over 10 percentage marks). However, by the end-of-year exam, students in Cluster 3

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2The logistics of measuring attendance were considered in this study but were seen as impractical with classes regularly comprising over 300 students.

3The measure of lecture attendance was based on students’ EVS responses. Students were regarded as attending a lecture if they recorded an EVS response for at least one question in that lecture. An aggregate of scores across the thirteen lectures established a lecture attendance index.
were performing similarly to students in Cluster 1, and both these groups had significantly lower scores than students in Cluster 2.

**Discussion**

The first stage of analysis presented in this investigation showed that students who were frequent users of an EVS and were relatively successful when they answered the lecturer’s questions performed significantly better in formal assessment tasks than those who both responded more often and more correctly over the course of the semester. Students who were relatively less correct in their EVS responses over the course of the semester tended to perform more poorly in formal assessments, regardless of whether they were high or low responders. This tendency persisted over time and in fact became more robust by the end-of-year exam. The results from the two stages of this investigation are broadly consistent in showing that there is a positive association between EVS usage and learning outcomes for students who are, relative to their class, of higher ability.

In the introduction of this paper, it was suggested that researchers have primarily outlined two ways in which EVSs can directly assist students’ learning: by encouraging active learning and through the provision of feedback. While the implementation of an EVS in the current investigation did not exploit peer instruction to the degree of other EVS implementations, the lecturer often led class-wide discussion and provided detailed feedback to students. In addition, based on Draper *et al.*’s (2001) suggestion that while formulating responses to questions, students would engage in beneficial cognitive processing, it was expected that EVS use would be positively associated with learning outcomes regardless of the correctness of the response.

Given that this was found not to be the case, it may be that processing or re-processing lecture material is only beneficial for particular students. It seems reasonable to suggest that some students – while thinking about the material contained in lectures – were not thinking about this material in a particularly constructive manner, as indicated by a high number of incorrect responses. These students may find that there are few advantages of using an EVS, particularly if they do not engage with the class-wide discussion or in the absence of extended peer-based discussion. Alternatively, students who were thinking about the material in a constructive manner – ‘rebuilding’ it in their own terms as Draper *et al.* (2001) suggest – may find using an EVS a distinct advantage. In the current context, therefore, it may be that any learning benefits associated with using an EVS are only apparent when students have some baseline level of content knowledge, which enables them to more easily cognitively integrate new lecture material with their current understanding.

### Table 3. Mean scores for Content and Correct Response indices for the three clusters that emerged from the sub-sample

<table>
<thead>
<tr>
<th></th>
<th>Content Response</th>
<th>Correct Response</th>
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<tbody>
<tr>
<td></td>
<td>M (SE)</td>
<td>M (SE)</td>
</tr>
<tr>
<td>Cluster 1</td>
<td>20.09 (1.72)a</td>
<td>0.19 (0.08)a</td>
</tr>
<tr>
<td>Cluster 2</td>
<td>20.59 (2.01)b</td>
<td>0.47 (0.08)b</td>
</tr>
<tr>
<td>Cluster 3</td>
<td>16.20 (1.01)b</td>
<td>0.24 (0.09)b</td>
</tr>
</tbody>
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Different superscripts within columns indicate significant differences.

### Table 4. Mean scores on two performance measures (Class Test and Exam) for the three sub-sample clusters

<table>
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<tr>
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<th>Class Test</th>
<th>Exam</th>
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<tbody>
<tr>
<td></td>
<td>M (SE)</td>
<td>M (SE)</td>
</tr>
<tr>
<td>Cluster 1</td>
<td>57.30 (2.60)a</td>
<td>51.28 (2.84)a</td>
</tr>
<tr>
<td>Cluster 2</td>
<td>73.05 (2.83)b</td>
<td>66.21 (3.09)b</td>
</tr>
<tr>
<td>Cluster 3</td>
<td>62.07 (4.45)b</td>
<td>49.30 (4.86)a</td>
</tr>
</tbody>
</table>

Different superscripts within columns indicate significant differences.
It is also possible that the results from this investigation simply indicate that higher ability students – students who get more EVS answers correct across the semester – perform better in the class-based assessments. This interpretation would suggest that there is little educational benefit of using an EVS other than providing the lecturer with an indication of either talented or struggling students. However, the fact that the ‘low EVS use/high ability’ group of students from the first analysis performed poorly in assessment tasks tends to undermine this conclusion. Nevertheless, the results from this investigation are somewhat inconclusive on this matter, given that a low usage/high ability category of students did not emerge in the second cluster analysis.

It is also worth considering that students who were high EVS users and showed relatively high ability were also performing well in class-based assessment because of an individually based variable that was not assessed in this investigation. That is, students who are more likely to (i) turn up for lectures, (ii) respond using an EVS and (iii) respond more accurately may also be students who are highly motivated, have a better fundamental understanding of the content material, are more interested in the content of lectures, are more confident in their academic abilities, are more self-directed, etc. It may be that one of these variables accounts for the positive association reported in the results. While we have attempted to control for attendance in this investigation, an array of other pertinent variables clearly exist in this complex learning environment. Further research based on theoretically derived models is required to assess whether some of these variables contribute to the association found in this study.

One of the unexpected findings from this investigation was the low proportion of correct responses given by students. Students who were performing well in assessments tasks still only managed to answer approximately half of the EVS questions correctly. It was not uncommon for students to correctly answer the lecturer’s questions only 20–25% of the time. This highlights the need for lecturers to consider and take care in ensuring that EVS questions are set at an appropriate level.

The fact that students were often getting EVS answers incorrect also highlights the importance of providing appropriate feedback in EVS-enabled lectures. Lecturers need to be sensitive to the responses that students give to EVS questions and tailor their feedback and lectures accordingly; they need to practice ‘contingent teaching’ (Draper & Brown 2004). As mentioned above, in the current EVS implementation, the lecturer provided feedback to students based on their aggregated responses. However, as students were rarely given the opportunity to respond to an EVS question for a second time, it is not possible to determine whether the lecturer’s explanation was effective in remediating students’ initial misunderstandings.

In addition to rarely being given an opportunity to vote again, students were given little formal opportunity to discuss their answers with each other. This activity, an important component of Peer Instruction, has been positively related to students’ learning (Crouch & Mazur 2001). If the current EVS implementation was modified to accommodate both repeat voting and peer-based discussion, it may be expected that both the number of students responding correctly and the mean proportion of correct EVS responses would increase. On the basis of the findings from this study, we would expect this to be associated with superior performance in end-of-semester and end-of-year assessment.

Implications for future research

Given that the frequency and correctness of students’ EVS responses over the semester were found to be associated with their performance in the end-of-semester assessment, a fruitful line of investigation will be to determine how early this association can be established. If students’ EVS responses during the semester can be established as a reliable predictor of subsequent performance in follow-up investigations, then these responses may be used to provide student support during the semester. Further analysis of returned EVS data will allow us to determine how early in the semester students’ responses predict their end-of-semester performance.

The analysis and general conclusions that we propose here raise questions and provide suggestions regarding the use and study of EVSs. We have already suggested possible ways in which the style of EVS implementation used in this study may be improved. In the future, we will consider what impact a greater emphasis on repeat voting and peer-based discussion
has on the association between EVS usage and learning outcomes reported in this paper. In our future research work, we will endeavour to measure students’ attendance, enabling us to use this variable as a covariate in our analysis of the association between EVS usage and performance. In addition, an important line of inquiry will be to consider the impact of other individually based variables, such as motivation, interest and academic confidence. We have already begun an analysis of the different types of EVS questions used in CS1P over a number of years at the University of Glasgow, looking particularly at their structure and difficulty. We are interested in focusing on students’ responses to these questions on more than one occasion and investigating the effectiveness of the remediation offered to students in lectures. In pursuing these areas of inquiry, we might be able to shed more light on not only the use of electronic voting technology but also on how broader educational factors impact on its use.

References


