Promoting interactive in-class learning environments: A comparison of an electronic response system with a traditional alternative

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Improved achievement and satisfaction arise when classes are made interactive (Hake 1998). Elliot (2003) reports positive results when an electronic response system is introduced in a microeconomics course, but recognises confounding due to the simultaneous introduction of interactive methods. In a larger study, Draper and Brown (2004) conclude that any novelty effect is short term, and that designing for interaction is crucial. We explore the use of handheld keypads against a show of hands in accounting classes already designed for interaction. Response method alone is changed in each class, alternating between the electronic system and a show of hands. A significant preference for the former continues to exist, suggesting that the technology affords an additional incentive to engage, interact and understand. Anonymity is explored as a plausible explanation.

INTRODUCTION

Encouraging students to engage earnestly in learning is a design challenge worth rising to, because quality learning outcomes are most likely to occur when students adopt a deep approach to learning (Ramsden 2003). With increasing student numbers and limited resources, large classes have become the default in more university courses. Large lecture theatres can be perceived as a place where some students, even in the early weeks of a semester, are tempted to slip into passivity, low engagement and surface approaches to learning (Biggs 1999). Neither of the possible subsequent outcomes – poor attendance or passive (or disruptive) disengagement – is desirable.

Active engagement and interaction are two important aspects in promoting deep approaches to learning which Ramsden (2003) notes is essential to achieving quality learning outcomes. Given that these are more difficult to achieve in larger classes, instructors faced with discouraging experiences can respond in several ways. They may blame students for poor concentration and motivation, or blame themselves for poor presentation skills and/or lack of charisma. Biggs (1999) declares both conclusions inappropriate. He maintains that instructors should focus instead on what students do, and treat it largely as a learning or course design problem. For example, rather than simply introducing presentation software (such as PowerPoint), with bells and whistles accompanying fancy transitions for each new slide, instructors should focus on designing learning (and assessment) activities that encourage students to be actively engaged. Kolb (2000) maintains that instructors should
accommodate different learning styles. For example, he notes that while reflecting on a lecture may suit some students, others may need more active experiences.

Encouraging peer discussion of relevant application questions and problems in large lectures is far more likely to get students engaged, interested and learning than a didactic lecture (Boud et al. 1999). Thus it is less about what the instructor does in the lecture theatre, and more about what the student does. It is what the instructor does outside the classroom in designing for student interaction and engagement in and out of class that matters. In a study of 6,542 physics students across multiple institutions, Hake (1998) shows that students in interactive courses significantly improved achievement over those in traditional ones. Furthermore, Wachtel’s (1998) review of student evaluation research shows that large classes do not necessarily receive low student ratings. He suggests that possible reasons include good instructors being assigned to larger classes, and/or instructors being motivated to be better prepared – both pointing to pedagogical design as the key to success in large classes.

While structuring time for in-class questions promotes active learning and interaction, learning can be further enhanced when students’ answers are elicited. The means by which students reveal their response to the instructor and fellow students – both to free response and multiple-choice questions – may impact the propensity with which students actively participate. The different means for students to provide their answers include: writing and submitting responses, being selected by the instructor to provide a verbal answer, participating in a show of hands, and selecting an option on a handheld electronic response system. With written responses, feedback is typically delayed to a future class – sometimes far in the future – and the likelihood of interaction is reduced. Even when a portable scanner is used for multiple-choice questions (Michaelsen et al. 2002) the feedback process is still cumbersome, because papers are scanned one at a time at the end of a set of questions. Delaying feedback precludes instructors from identifying and addressing gaps in student understanding of introductory concepts that are necessary knowledge for more advanced material.

Selecting a student from the class to respond is an immediate response method that benefits other students, as different perceptions of the answer are discussed. While asking those who might know the answer to put up their hand may overcome the intimidation of being selected, even a confident and knowledgeable student may be reluctant to display their response in a large class if the student is shy.

Asking for a show of hands for each option (‘hands up if you think the answer is A’) may save time in getting a correct response, and allows students to gauge their relative understanding. However it does not eliminate intimidation as some peer pressure remains (Poulis et al. 1998) particularly if concepts are relatively new, or students are uncertain of their grasp of the material in question. Students may also be influenced by their peers’ choices, for example being reluctant to reveal their choice if others are obviously not of the same view. This peer influence may be removed if preferred responses are revealed simultaneously, using a different coloured paper for each option (e.g. blue for ‘B’). Minor time efficiencies may also be achieved with this approach (Harden et al. 1968). However obtaining an accurate count of hand or paper responses – and distributing the coloured paper – is cumbersome, particularly in large classes.
An electronic response system (ERS) enables students’ responses to multiple-choice questions to be readily collected, and the aggregated responses to be provided back to them immediately. Students use a small, wireless, handheld keypad (the size of a very small mobile phone) to indicate their answer to questions posed by the instructor (typically, but not necessarily, using presentation software). Recent advances have reduced the cost of such systems and made them more flexible, as wireless handheld technology has replaced permanently wired systems. Answers are captured by a wireless receiver, and the software immediately aggregates the answers. Feedback to students of aggregated responses is possible after each question, typically projected using presentation software as a chart (e.g. a histogram) on an overhead screen.

Instructors can use any of these in-class question and response methods to detect gaps in understanding, and thus initiate early formative feedback. With an electronic system, however, an instructor has the flexibility to not feedback the aggregate responses immediately after student responses to a question. Reasons for this may include a desire to use the aggregate feedback to plan subsequent teaching strategies, or alternatively to prove a particular point to students, such as the improvements in understanding possible with peer discussion of a question following an individual attempt.

The flexibility of the class-based ERS allows its usage in a range of ways to engage students. Examples of how questions can be framed as multiple-choice questions or decisions or responses include:

- Formative and summative assessment activities, where students do practice or for-credit questions along the lines of typical multiple-choice questions, covering definitions, recall or rules-based types of problems (e.g. Draper & Brown 2004; Elliott 2003; Burnstein & Lederman 2001).

- Formative feedback and awareness-building learning activities, typically achieved through more complex questions that are rewritten as multiple-choice questions to promote discussion. Examples include decision-making questions, problem-solving questions, theory simulations, and human experiments which can be completed either as individuals, with a peer student, or in group contexts (e.g. Banks 2003; Jones et al. 2001; Draper & Brown 2004).

- Peer review as formative feedback, and/or assessment of in-class questions, completed as individuals (e.g. oral presentations and posters), or in groups (e.g. role-plays) (Draper & Brown 2004; Banks 2003).

An ERS can also be used to assist instructors with their teaching and administration. Beyond fairly primitive administrative uses such as keeping attendance records, formative feedback on lecturing style, and level of student preparation or fatigue (Shapiro 1997; Mitchell 2001), instructors report using electronic response systems for summative feedback, and evaluation of the course (e.g. Draper & Brown 2004; Banks 2003). Of course, the application of an ERS in a class can achieve multiple outcomes. For example, Burnstein and Lederman (2001) report dramatic improvements in attendance when scores on ERS-based questions are worth more than fifteen percent of a grade.
Student satisfaction appears to be a common theme over several decades of research in different contexts (Judson & Sawada 2002), and in an institution-wide context over a number of years (Draper & Brown 2004). In a microeconomics course, Elliot (2003) reports increased student enjoyment of lectures when an ERS was used, yet at the same time recognises the potential confounding of this result, since more active learning strategies were simultaneously introduced with the ERS.

Draper and Brown (2004) report a two-year institution-wide program using electronic response systems, and conclude that while students appreciate its use, any novelty effect is short term (five to 50 minutes). However the result of early research on the (pre-wireless) use of an ERS, showing no impact on student achievement (Bessler 1969) has been a consistent theme – as shown in Judson and Sawada’s (2002) review of several decades of research. That technology adds no significant value in itself is no surprise, given the long history of educational technology research summarised in Russell (1999), and the nationally-funded Australian study by Alexander and McKenzie (1998), which all support this view. More recently, in longitudinal research with over 80,000 students, Kirkwood and Price (2005, p. 272) note that ‘the medium itself is not the most important factor in any educational programme – what really matters is how it is creatively exploited and constructively aligned. The educational benefits that students perceive as gains from using ICT are more significant than the intrinsic characteristics of any particular medium.’

Judson and Sawada (2002) conclude their ERS review by stating that the ‘only positive effects upon student achievement, related to incorporation of electronic response systems into instruction, occurred when students communicated actively to help one another understand’ (p. 178). Designing for peer interaction is crucial to student learning. Crouch and Mazur (2001) report student achievement on standard physics diagnostic tests over a decade of ERS use with peer interaction at Harvard University. They found, for example, 40 percent of students correct before peer discussion and 72 percent after, and conclude that the success of peer interaction does not depend on a particular response method.

If interaction, and peer interaction specifically, are the important components of the student experience, are the costs of an ERS teaching strategy unnecessary? Although equipment costs (about A$15,000 for the software and hardware for 150 individual handsets) continue to decrease with technological advances, there are ongoing costs from regular usage beyond the once-off cost of learning to use the equipment. In comparison to the simpler zero-cost option of a show of hands, the main extra burden is setup/setdown time (including the distribution and collection of handsets to students in class, collection and return of the mobile equipment from a central secured location, and setting up and testing the infrared or radio receivers). Some time may be saved with an alternative strategy currently being marketed by some publishers, where students buy the handset when they purchase the textbook. However this cost transfer to students has equity implications that may limit its application in some contexts.

Previous research has noted costs of regular ERS usage including generating in-class questions, learning to use presentation software, and redesigning a class session to allow for questions and interactive peer discussion. However these are not marginal costs of introducing and using an ERS. If an instructor has already heeded the finding that pedagogy and not technology matters, they will already have incurred the marginal
costs of redesigning classes to be interactive. If so, then an ERS may be perceived as an unnecessarily costly option. The main marginal cost is the setup/setdown burden that impacts both students and instructor, particularly if equipment is not installed in a classroom. Beyond this ongoing marginal cost, there are possible marginal costs of equipment failure. If an instructor is using the system for assessment, and the equipment fails to record the responses on file, the students are likely to be upset. Furthermore, the instructor might be embarrassed and have to arrange an alternative assessment, which is time consuming. The marginal costs of equipment failure are smaller when it is used only for formative purposes.

Since previous research has confounded the costs and benefits of introducing an ERS with various aspects of pedagogical redesign – such as peer learning and interaction – that are triggered by its introduction (Draper & Brown 2004), our research is motivated by the desire to focus on comparing alternative teaching strategies where efforts are made to control for that confounding. The objective of this paper is therefore to explore the effects on the student experience of using different response methods to in-class questions – namely a handheld electronic response system, and the simpler method of a show of hands – holding constant other aspects of a constructivist pedagogical design.

**METHOD**

The impact of this technology in supporting student engagement and learning over the simpler ‘show of hands’ option is explored. Allowing for the difficulty in using an experimental research method with human subjects in an action research project, we chose a quasi-experimental research design. We explored the quality of the student learning experience in a six-week intensive accounting course with two classes per week. All aspects of the lecture theatre teaching strategy except response method were held constant.

<table>
<thead>
<tr>
<th>Teaching strategy</th>
<th>PowerPoint presentation</th>
<th>Multiple-choice questions</th>
<th>Prior peer discussion</th>
<th>Response method</th>
<th>Post-response discussion</th>
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<tbody>
<tr>
<td>ERS</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Electronic</td>
<td>Yes</td>
</tr>
<tr>
<td>Non-ERS</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Show hands</td>
<td>Yes</td>
</tr>
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</table>

Table 1 summarises the two teaching strategies:

- Presentation software (PowerPoint), loaded on a laptop connected to a data projector, was used to display learning material in every class. A software add-in provided an additional PowerPoint toolbar to enable the functionality of the ERS.

- Multiple-choice questions (MCQ), prepared in advance of each two-hour class, were punctuated throughout the instructor’s presentation approximately every fifteen minutes. The questions were mainly formative rules-based problems, where choices included common misconceptions.

- Prior to indicating their preferred response to the MCQ, students were encouraged to engage in reciprocal peer learning with one or more neighbouring students. The time
allowed varied with the difficulty of the question, and the instructor’s estimate of how long it might take to complete, moderated on the day by the perceived speed of completion.

- Students indicated their responses in two possible ways. Responses were indicated using the ERS wireless keypads in one class and in the next class by a show of hands. For this pilot project, the hardware (receiver and keypads) and software for the ERS were borrowed from a supplier and carried to each class along with the laptop. Keypads were distributed to students at the beginning of the class and collected at the end – one keypad for every three students to encourage peer interaction. While the instructor (and students) could only estimate the proportion of responses for each option when a show of hands was used, the ERS enabled exact aggregation. Using a data projector connected to the laptop, the ERS also enabled the projection of a clear and appealing display of the responses for each option, with the correct response highlighted in green. In the manual ‘show of hands’ approach, the instructor would simply announce the correct option. No assessment value was attached to responses.

- Following the receipt of student responses to each MCQ, the instructor led a further discussion to clarify possible misunderstandings.

At the end of the course the students were surveyed \((n = 111)\) to ascertain their reflections on the learning experience, where interaction and peer learning with punctuated questions had been constant for each class, but student response method only had alternated. A paper-based survey was used rather than the ERS, to collect students’ free response comments as well as ratings. A five-point Likert scale (strongly disagree to strongly agree) was used to ascertain student perceptions on three pairs of rating statements. Each pair sought ratings on an important aspect of learning design (e.g. interaction), for which all efforts had been made to hold that factor constant. If the technology is truly in itself neutral, then we would expect no significant difference in students’ perceptions of that aspect (e.g. interaction) between the ERS and non-ERS teaching strategies.

The first pair of statements rated perceptions of interaction in lectures with the ERS system and the non-ERS ‘show of hands’ strategy. The second and third pair rated student perceptions of increased understanding, and ability to gauge his/her own understanding, under the two teaching strategies. If pedagogical design is the key, and not the incorporation of technology, then the ERS strategy should simply be an unnecessarily costly means for gathering responses when compared to a show of hands. Paired \(t\)-tests for significance were undertaken to ascertain this. To check for possible confounding factors due to culture and other demographic differences suggested in the literature, chi-square tests were undertaken on gender, age, hours in paid work while studying, first language, local or international student origin, and disability. The free responses comments were summarised, grouped and analysed.

RESULTS AND DISCUSSION

Table 2 displays the students’ responses to the three paired statements that draw student attention to the increased level of interaction, increased understanding, and ability to
gauge understanding from the two teaching strategies. While the two strategies apparently differ only in response method, all paired t-test statistics are highly significant.

The first pair of statements in Table 2 indicates that the ERS teaching strategy resulted in a significantly higher rating \( (p = 0.000) \) by students of increased interaction (68% agreement, versus 14% agreement for the non-ERS strategy). The teaching strategies used were purposely constructed and executed to ensure that high student-instructor and student-student interaction existed in both scenarios, and therefore this significant difference needs some plausible explanation.

<table>
<thead>
<tr>
<th>Table 2: Student perceptions of teaching strategy ((n = 111))</th>
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<tbody>
<tr>
<td>Teaching strategy increases the level of interaction in lectures.</td>
</tr>
<tr>
<td>( \text{ERS} )</td>
</tr>
<tr>
<td>( p = 0.000 )</td>
</tr>
<tr>
<td>Agree / Strongly agree</td>
</tr>
<tr>
<td>68%</td>
</tr>
<tr>
<td>14%</td>
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Teaching strategy increases my understanding of material content gained during lectures.

<table>
<thead>
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<th>Teaching strategy increases my ability to gauge my understanding of material content during lectures.</th>
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<tr>
<td>( \text{ERS} )</td>
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<tr>
<td>( p = 0.000 )</td>
</tr>
<tr>
<td>Agree / Strongly agree</td>
</tr>
<tr>
<td>61%</td>
</tr>
<tr>
<td>24%</td>
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</table>

One possibility, namely anonymity, deserves further conjecture. As the ERS affords students anonymity, and because they knew they would not be called upon to provide a public response, this perhaps provided more freedom to engage in the student-teacher and student-student planned interactions. In contrast, the non-ERS strategy may result in students adopting a “wait-for-the-answer” strategy. Draper and Brown (2004) observed ERS use in small classes, where students knew each other well and had not previously hesitated to join an oral group discussion. When students were uncertain of the answer to a question, they became more reluctant to join a discussion without the ERS. This was also noted by Crouch and Mazur (2001). Poulis et al. (1998, p. 439) suggest that this affordance extends to a reduction in fear and potential peer ridicule. Banks (2003, p. 43) suggests that cultural background may be significant, with a preference for ERS from those students for whom criticism is problematic. In testing for such demographic differences in perceptions, the chi-square tests revealed no significant differences in any variables. Students’ first language, local or international origin, gender, age, hours in paid work while studying and disability were not significant factors.

A possible contributing explanation became apparent after the trial, when the instructor was challenged as to whether he was really able to keep the classes the same in every respect except for the use of the ERS. He noted that the anonymity afforded by the ERS
strategy affected his behaviour as well – he felt freer to encourage student engagement and interaction when he could do so without offending any student because they would be anonymous. However, in the large lectures when the ERS was not used, the instructor reported that he was less inclined to wait or insist that all students show hands to indicate their response, because he felt that such insistence may have been insensitive or discouraging. Perhaps students perceived that his lower propensity to insist that they participate meant they were less motivated to engage and to interact. A further possibility is that the instructor allowed either too much or too little time for interaction and response with the non-ERS strategy, because he did not have the ability to accurately gauge how many students had an answer, but were simply reluctant to indicate it through a show of hands. With the ERS strategy, it is possible to ascertain if students have not responded. This is an opportunity for future research.

The second pair of statements in Table 2 indicate that when it comes to students’ understanding of the material, a significant difference ($p = 0.000$) also exists between the percentage agreement with the ERS (61%) and that without it (24%). This reported improvement in understanding is a positive outcome of the ERS strategy. Increased interaction and peer learning when the ERS was used may have arisen for similar reasons to those outlined above. It is possible that students engaged more seriously with the question, and interacted more freely with their peers leading to greater understanding, because they knew that the subsequent method for indicating their response using the ERS afforded them anonymity to peers and the instructor. A contributing reason to engage could also arise from the unconscious behaviour of the instructor, evident with the ERS strategy, where he was more insistent that students actually engage. Draper and Brown (2004) propose that increased understanding arises from anonymity because it induces students to pick a definite answer even when they are quite uncertain, and it is this that encourages student effort to produce an answer. While this may be similar to the pressure on a juror to make a decision when they feel ill-equipped to do so, it is different in that a student’s decision is not irreversible. Instructor feedback on wrong answers is likely to motivate effort to clarify and understand after class.

The final pair of statements in Table 2 indicates that students rated the ERS strategy significantly higher ($p = 0.000$) in terms of improving their ability to gauge their own understanding (67% and 21% agreement respectively). This result is not quite as surprising as the others above as the ERS strategy allows a more visually obvious representation of results for students, since it produces and projects a histogram of responses with the correct option shown in green. A student can gauge their own understanding immediately with either teaching strategy. However with the second aspect of gauging understanding, namely gauging understanding relative to peers, the ERS strategy provides an exact indication of response numbers as compared to approximations with a show of hands. With the non-ERS strategy, the size of a class and students’ ability to recollect the distribution of hands affects their ability to gauge other students’ responses. In contrast, the ERS strategy enables automatic aggregation and projection, allowing relative understanding to be easily gauged. Furthermore, the instructor observed a higher response rate with the ERS than the non-ERS ‘show of hands’ strategy, suggesting that it was easier and more accurate for students to gauge their understanding relative to peers with the former. A greater response rate is likely to arise because the ERS afforded anonymity, and greater interaction and engagement, and not simply because students randomly selected a response.
As previously noted for interaction, demographic variables were not significant in explaining differences in preferred use or non-use of the ERS.

A total of 109 free-response comments were received from the 111 respondents. The majority (70 responses) related to positive aspects of the ERS strategy. The overwhelmingly most positive aspect was the interaction provided by the ERS (28 of 70 positive comments), consistent with the quantitative ratings. Comments referred to increased interaction specifically or indirectly in various ways, such as ‘increased participation’, ‘more active learning’, ‘more involved’. While anonymity cannot be specifically identified as a contributing factor in such statements of improved interaction, a further five comments did specifically identify anonymity as beneficial. Examples include ‘everyone gets to participate without coming out’ and ‘I don’t know why I am afraid to ask the lecturer questions’. It was in fact these comments regarding anonymity that encouraged our further pursuit of it as a plausible factor explaining student perceptions of the ERS strategy, over and above those aspects of interaction and peer learning that were specifically designed into both strategies. Other positive aspects commented on were the increased understanding (11 responses), the fun or novelty aspect (9 responses), and the ability to gauge understanding (6 responses) in both absolute and relative terms.

Only 32 of 111 students indicated aspects of the ERS strategy that could be improved. The majority (79 students) either left this blank, or noted ‘nil’ or ‘nothing in particular’. Of the 39 suggested improvements, thirteen related to technical aspects of using the equipment. Eight of these thirteen comments noted an undesirable amount of time consumed at the beginning of the class while the equipment was being set up, or technical problems were being resolved. Five students commented that the ERS strategy needed to improve the reception of the infrared signal, so that students did not have to press the keypad more than twice. The remaining ten suggestions for improvements related to having more response keypads (noting that sharing with up to three students was undesirable). While it was possible to provide one handset per student, a decision not to do so was specifically made, because peer learning was part of both teaching strategies. Perhaps insufficient time was provided to student groups to discuss and convince each other of the correct answer, and hence some students wanted their own ability to respond. Several students noted that it would be preferable to have more discussion type questions.

Of course, there are limitations to generalising these results. First, positive student support for the use of the ERS strategy might be expected, if for no other reason than the Hawthorne effect (Mayo 1933). However, the instructor drew no attention to the research aspect of the two teaching strategies. Second, some positive perceptions may arise because of the novelty of the ERS. However, only nine students specifically commented on novelty, and this is consistent with Draper and Brown (2004) noting this as being short lived (five to 50 minutes). Third, while anonymity is suggested as a plausible explanation of the strong preference for the ERS strategy over the non-ERS strategy, the research method did not specifically seek student feedback on it. This is worthy of future research. Further, text-based anonymous responses, not possible with the simple ERS, are also worthy of future research. McCabe and Lucas (2003) note such benefits in a teaching computer laboratory setting. However, as PDAs and tablet PCs become more affordable, and wireless-enabled environments become more common, it will be easier to accommodate text-based explanations in a typical lecture setting.
Prensky (2005) notes that a more imminent solution may be possible. He suggests cell phone messaging as a viable technological option, since the penetration of cell phones among students is so high, and the development kits for such uses are so cheap.

CONCLUSION

Large classes have become the default in more university courses. The introduction of in-class questions and peer learning to promote increased interaction and understanding is a common teaching strategy in such contexts. Requiring students to respond to such questions can assist this learning. While there are a variety of traditional ways in which students can indicate their response, such as written, show of hands or being selected, technological options are becoming more readily available. A handheld electronic response system that enables students to respond to in-class questions is a technological and costly alternative to asking students to respond with a show of hands. This technology-supported system elicits captures and aggregates student responses to in-class multiple-choice questions, and allows for immediate feedback even in large classes.

Previous ERS research concludes that it is the pedagogy and not the technology that matters (Draper & Brown 2004). However, ERS shows promise for ‘facilitating earnest discussion’ (Judson & Sawada 2002, p. 167). Previous research has not specifically separated the impact of pedagogical changes and the use of ERS technology in conjunction with those changes. If interactivity in pedagogical design is the key to an improved learning experience, an ERS needs to be compared with a traditional approach where interactivity is also present.

In this research, the student experience was designed so that vigorous peer discussion was encouraged, irrespective of whether students used the ERS or a show of hands to indicate their answer to in-class questions. Therefore, minimal differences in student perceptions of the learning experience were expected. However, students perceived a significant relative advantage of the teaching strategy using the ERS in relation to interaction, understanding, and gauging understanding. This is consistent with Ward (2003), who contends that the ‘engagement of the student on a continuous and no-risk basis clearly changes the classroom paradigm’. There were no significant differences in perceptions due to any demographic variables, including first language, local or international origin, gender and age.

Anonymity is explored as a factor driving this perception. In contrast to a show of hands, the ERS affords students with anonymity from their peers and instructor. Whether or not students are confident that they know the right answer, their ability to remain anonymous may encourage engagement and interaction. Increased engagement is more likely to result in a deeper approach to learning, and is therefore more likely to lead to increased understanding and learning outcomes. Whether facilitated with an electronic response system or not, anonymity, as a driver of student engagement to learn and participate, is worthy of closer scrutiny and future research with this and other educational technologies.
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