Fun and feedback at the press of a button

Debbie Richards
Computing Department
Macquarie University

Catherine Braiding, Alan Vaughan
Physics Department
Macquarie University

A common phenomenon across disciplines and universities is that students complain that they do not receive enough feedback, even when student evaluation forms indicate satisfaction in other areas such as teacher competency and enthusiasm. On the other side, but less considered, is the lack of feedback that teachers receive as they struggle to get students to participate and engage with the learning process. While technology does not offer an automatic solution, keypad-based automatic response systems do offer the potential to let both parties know how well the learning outcomes are being achieved in a timely and cost-effective manner. We have just completed two years of pilot trialling of such technology at our university in the Computing and Physics Departments. This paper reports our experiences together with the findings of others.

Keywords: feedback, collaborative learning, socratic learning, keypad-based technology, personal response system, computerised audience response systems (CARS)

Introduction

Student motivation, engagement and timely feedback are critical factors affecting learning. It is becoming increasingly important for teachers to make learning enjoyable and to some extent entertaining. Currently individual teachers face the challenge of how to present material in more interesting and innovative ways and to encourage greater problem solving and engagement with the material by students. Additionally, students and teachers need to know whether the learning objectives are being achieved before the final exam. The use of keypad-based technology, known by a number of names including Personal Response System or Computerised Audience Response Systems (CARS), offers the opportunity to concurrently address the engagement, enjoyment and feedback issues. By providing questions for consideration by the class to your Powerpoint slides, students are encouraged to actively participate in lectures and tutorials in a fun way that also gives them instant feedback via a wireless handheld keypad while remaining anonymous. Thus, the technology supports a Socratic method of learning with a twist: instead of students learning by asking questions, they learn by being asked questions.

Many lecturers currently use questions in such forms as problem statements, case studies, examples and quizzes to get students to interact and participate. In our experience, students are often reluctant to venture an answer even for structured problems requiring students to simply vote whether they do or do not agree. The reasons why students do not participate may include embarrassment, uncertainty of the answer or what is required and not wanting to look un-cool by doing as the teacher requests. These impediments to getting students to fully participate can potentially be reduced via the use of the keypad-based technology.

Not only does immediate feedback to the class enable the lecturer to correct widespread deficiencies in understanding but individual class members get feedback on how they are doing compared to the rest of the class without being singled out. The shy student can have as much say as the more assertive students. When used for group activities the technology can enhance team identity and membership.
The keypads can also be used for capturing actual responses for feedback and assessment purposes by identifying to whom a device has been allocated. This is helpful for inclass tests that may be conducted weekly in lectures and/or tutorials as part of the assessment structure or for infrequent assessments such midterm tests. Mid-term tests have been found to be a good strategy for encouraging students to stay on top of the material and serves as a wake up call to both the students and the teaching team about the current level of ability of the students. However, manual marking and reporting of these inclass tests can

be onerous due to the time requirements and may not be possible due to budgetary constraints. With the decrease in IT students together with ongoing pressure to improve our quality of teaching, a solution, such as that offered by the Keypad technology, which automates assessment and provides feedback may have an important role to play.

While some benefits of the keypad technology have been considered we acknowledge that technology does not offer an automatic solution to the various problems experienced in education. From an economic point of view it is often difficult to find any evidence of the benefits of technology (Landauer, 1995). However, when there is "a good fit between a particular learning situation and specific technical solution" striking positive results can be found (Draper, Cargill & Cutts, 2002). CARS have been employed for teaching in many fields including: physics; business; statistics; mathematics; information systems; pharmacy; psychology; medicine; and electrical engineering, and in many universities nationally and internationally including: Melbourne University; Monash University; University of South Australia; Glasgow University; Brisbane Graduate School of Business; Indiana University; Columbia University Medical Centre; and University of Massachusetts. In this paper we report our usage of the technology in the Computing and Physics Departments which was funded via a teaching grant as a pilot for the rest of our university.

In the next section we provide an introduction to the technology and some of the uses reported at other institutions. Following that, we describe the ways in which we incorporated the technology into a few of our second and third year courses and the results of having done so. Then we describe the methodology we used to develop the content and integrate it with our existing courses. Finally, we conclude with some discussion and future directions.

The technology

Keypad technology allows individuals to use a small numeric keypad to communicate with a computer system via infrared or wireless. The responses from individual keypads can be received and collated for each session and used to provide instant grading, polling or just feedback to the participants. Despite the responses being in one direction (from keypad to receiver), the technology facilitates a two–way communication channel between the teacher (who posed the question on the slide) and the student (who responds to the question).

An early Electronic Classroom Communication System (ECCS) known as ClassTalk used scientific calculators hardwired to a network (Abrahamson, 1999). Another example is EduCue which offers a personal response system known as InterWrite[i]. We have been using the Turning Point[ii] software and KEEpad[iii] devices. TurningPoint can be used with a variety of response devices including infrared and radio frequency keypads as well as networked PDAs, laptops and desktops. Figure 1 shows what a typical handheld device from KEEpad looks like. Products such as TurningPoint offer sophisticated presentations, question-style formats, analysis and reporting features.

Figure 1: A typical KEEpad

Setup is simple and requires a three step process of:

1 Install TurningPoint software which adds a specialized toolbar to MS Powerpoint;

2 Set up devices by connecting the receiver to the computer and following in the installation screens; and optionally
3 Setting up the participant list. Step 3 is only required when the teacher is interested in keeping track of the responses of individual students for marking purposes or understanding the responses by demographic charactistics.

SOURCE: http://www.keepad.com/pricing.php

Prior work

The usage of audience response technology is not new or uncommon. We present here a sample of the findings and helpful hints of others who have used the technology. For example, after years of experience within its various courses, the Columbia University Medical Center for Education Research and Evaluation concludes that audience response systems technology has the potential to: "Promote active learning and discussion; clarify and expose misconceptions; support interactive case study analysis; enhance retention of information; assess students' mastery of content; adjust lecture emphasis according to needs; elicit diverse points of view when there is no correct answer; and give immediate feedback to students" [iv]. The site also stresses that "clear educational objectives" are needed to drive the design of slides. A useful tipsheet containing best practice and common pitfalls is provided at: http://library.cpmc.columbia.edu/cere/web/facultyDev/ARS_handout_2004_tipsheet.pdf. Another leader in the application of technology in teaching, including the use of keypad-based technology, is the Physics Department at Indiana University, as evidenced in the 70 page summary by Hake (1999).

Dufresne et al. (2000), also from a US physics department, points out how students and teachers need to learn to modify their behaviour and particularly their "habits of mind" to fit the new technology. They offer a model-based design paradigm that is founded on cognitive research results and the premises that: proficient problem solving requires structured knowledge; structuring knowledge requires certain cognitive processes and it is possible to create activities and experiences to stimulate beneficial cognitive processes.

Draper has developed a website[v] that offers assistance with issues related to forming questions such as: "decomposing a topic the audience was lost with", "selecting the next question" "designing a bank of diagnostic questions" which can be used to assist in the design and evaluation phases described later. Sokoloff and Thornton (1997) have novelly used the technology to capture the predictions of students during physics experiments to improve engagement and understanding. Their studies have found that persistent learning is achieved by this means as the concepts were later assessed in final exams with a 7% improvement in results.

It is interesting to note, that just as medicine led the way in introducing problem based learning into its degrees, it seems again that the traditional sciences such as medicine, physics and biology have been early adopters of ECCS's such as the keypad.

Within the field of mathematics, Butler and Butler (2006) provide an up-to-date summary of the uses of personal response systems, including recommendations for planned improvements and future research. Closer to home, from a teaching domain and geographic perspective, Banks (2003) has extensively used keypad-based technology to support group decision-making processes in the information systems (IS) area. Sharing of views, greater understanding and a more reflective approach to learning were achieved in four separate uses of the technology: peer review of student presentations; quality assurance subject evaluation; peer review of collaborative group-work; and sharing interpretations. Banks (2003) has found keypad systems to be useful for enabling: communication; learning desire and commitment; customised instruction and data collection with both undergraduate and postgraduate populations. Also in the IS domain, Tsvetinov, Abercrombie and Do (2005) used KEEpads with first year students to get them talking together without the "bounded rationality" which typically occurs with group thinking. Additional related work is described in the next section intermingled with the description of our usage of keypad-based technology.

Case studies using KEEpad

Our first usage of KEEpad began in Semester 1 2005. Three units were third year units that involved a year-long group-based project that also required acquisition of some new subject material related to software engineering such as project management, modelling, quality and change control. In 2006, two second year subjects were chosen for trailing the software: a second year programming unit and a second year astronomy unit. We are currently preparing materials for use in a first year programming unit (we do not present any discussion of this unit). The types of presentations we created using TurningPoint, and employed as indicated in the following case studies, followed one of three styles:

- Template 1: Standard question/result mode (multiple choice questions, create histogram) for use in lectures/tutorials to assess understanding;
- Template 2: Class discussion mode that poses a question, lets groups form and be identified in the presentation. Groups then get together to discuss the option chosen to defend to the rest of the class;
- Template 3: Peer assessment.

COMP229: Object oriented programming practice

Student Population: Around 200 2nd Year, sometimes 3rd year, Computing students.

Unit Description: This unit bridges the gap between introductory programming and larger multi-person projects by considering the use of object-oriented techniques to produce intermediate-sized software.

Practical exercises emphasise the importance of programming practices such as appropriate documentation, systematic approaches to debugging and testing, and the use of software development tools. This unit is a first introduction to JAVA and builds on 1st year C++ units.

Keypad Technology Learning Outcomes (template 1 only): Test out current knowledge. Motivate discussion by identifying weak areas of student knowledge. Provide two-way feedback and encourage participation. Exam preparation.

This unit is a traditional Computing unit that does not involve project or group work, except for one of three assignments. Use of the keypads in this unit was along the lines used in similar types of units at other institutions. At Monash a CARS was used in a second year electrical engineering course (Su, 2003) to encourage students to pre-read lecture materials, to run short tests to determine student understanding of a particular section, for assessment in tutorial and mid-semester tests, to develop multichoice questions by student groups to pose to the rest of the class.

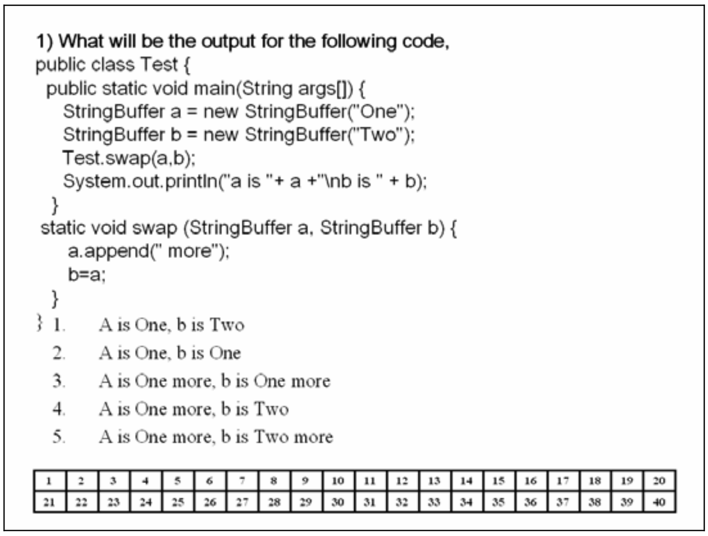

Figure 2: Screen shot of a question used in COMP229

Keypads were first used at the end of Week 4 to assess the students' grasp of the fundamental concepts. Some questions related to snippets of code and whether they would compile, run or what output or error message would be produced. See an example in Figure 2. Other questions related to more theoretical concepts such as the differences between various collection or exception classes or layout managers, how Java works, the use of JUnit, the order of constructors, and so on. We found in this domain that many multiple choice questions could be found on the internet, thus saving the time to design a question. Also, multiple choice is commonly used in certification exams and thus testing using this paradigm was also valuable practice for those wishing to go for certification.

Due to lecturer changes, the keypads were not used again until week 13 when students used the technology as practice for the exam. To fit with the use of the keypads in 2005 and 2006, the exam was also changed so that one quarter of the exam used multiple choice questions that could also be automatically marked (but not via the keypad system).

In the first year we conducted a survey, via the technology, to determine how well the technology was received by the students. Based on the responses of 40 students (we only had 40 keypads – distributed on a first come basis, others participated indirectly) on a five point likert scale students responded that:

- They found the keypads easy to use (4.2);
- They enjoyed using the keypads (4.1);
- The keypads helped me participate (4.31);
- The keypads helped me learn/revise (4.0);
- They would like to use the keypads again (4.3).

Comments were solicited from all students. Only the following were received:

- "excellent and fun";
- "it's really fun";
- "wowwwww… it was amazing…. and funny …. and encourage me and challenge me to study more and more. Good on you for doing something unusual but useful";
- "Overall very good";
- "we need more of it. Keypad ams the pwnzor!!Ione";
- "next time have enough for the whole class";
- "it was fun and educational";
- "perhaps run the questions faster so more questions can be fit into a 1 hour lecture".

In all sessions using the keypads in this unit, there seemed to be a feeling of excitement or a buzz in the air. It could be that the technology is still very novel and that over time, the effort involved in distributing and collecting the devices would counteract the positive mood currently experienced. When a question had many wrong answers, some time was spent on explaining why one or more of the options were right or wrong. At times it was quite a surprise to both the students and the lecturer when a question was poorly answered. Tailoring of the set of questions was done on the fly according to the amount of discussion, time and apparent interest or weaknesses of the students. For example, questions covering similar material could be skipped if the concept seemed to be understood.

We would have preferred to be able to incorporate questions into any lecture throughout the semester and at any point within the lecture that required some discussion, change of pace or test of understanding. However, it was quite a logistical hurdle to carry a notebook, a pouch of 40 keypads, the sensor and stand across campus. To provide an orderly means of distribution and honesty system, we asked students to place their student card in the pouch of the keypad they had taken from the pouch at the start of lectures, and return the keypad at the end of the lecture. If we had 200 keypads, this process may have been worse, though we would have distributed pouches of keypads in various locations so it may not have been significantly more difficult. We discuss some alternatives to the current technical/logistical limitations of the technology in the final section of this paper.

COMP340: Systems engineering project

Student Population: Up to 40 3rd year Bachelor of Computer Science students with GPA ≥ 2.75.

Unit Description: This unit introduces students to the concept of the project process and the many activities which must come together in a successful systems development project. This is achieved through a lecture stream and being a member of a team of 4-5 students working on a year long industry-based project.

Keypad Technology Learning Outcomes (template 3 only): Peer assessment of student presentations. (These presentations replaced lectures. Students were given a topic by the unit convenor which they researched and then gave a 20 minute presentation to the convenor and their peers based on the text book and other relevant material). Encourage better presentation and audience attendance and participation. Improve (perceived) equity of assessment.

The keypads made it feasible to acquire the approx. 480 responses (40 students * 4 assessment criteria (content, presentation, materials, discussion) * 3 presenters) each presentation session. At the press of a button the lecturer could determine the average mark for each criteria, the overall mark and standard deviation, allowing comments and the overall marks to be emailed to the presenter on the afternoon following the presentation. The rationale for changing to peer assessment included:

- Peer assessment has been found to be a valuable learning mode;
- The mark is derived from multiple assessors rather than based on one person's opinion. This takes the pressure off the lecturer to appear equitable;
- Students in the audience are more encouraged to attend and listen as they get to give their input;
- The student presenter is encouraged to make the presentation more engaging.

Additionally, the keypads were made available to the students to encourage audience participation in their presentation and some students took advantage of this option with good results.

In a study conducted by Banks (2003) involving keypad-based peer review, the following ten presentation marking criteria were used: introduction and summary; up-to-date; accuracy; comprehensive; structure; clarity; timing; pace; audiovisual aids; and interest. While there is potentially merit in doing so, we note that after only two weeks of collecting separate responses for all of our four criteria, students collectively requested that they be allowed just to enter one overall mark per student – rather than distinguish between content, presentation, materials and engagement.

The most interesting outcome of the use of keypads for peer assessment of the student presentations in this unit was that almost without fail, the average score given by the students was within half a mark of the overall score that the lecturer awarded. This is surprising because even though students gave one mark out of 10, the average across the group matched closely with the lecturer's score which was broken down into the four components and weighted (content (3), presentation (2), materials (1) and engagement (2)). Note, however, that sometimes the standard deviations were very large. Such a result would take the burden off the marker and department budgets and provide a further motivator to use peer assessment in addition to the rationale offered above.

COMP345/346: Computer science project / information systems project

Student Population: About 20 3rd year Bachelor of Information Science/ Technology Students.

Unit Description: This unit provides an introduction to software engineering, describing the software life-cycle and the techniques that can be applied in each of its stages. Approximately half of the material is concerned with methods for analysis, specification and design, including the functional and object-oriented approaches. The remainder addresses issues of management and quality assurance. These units involve a substantial group project drawn from the full breadth of IT applications (for COMP345) or involving modern database technology in an information systems setting (COMP346).

Keypad Technology Learning Outcomes (templates 2 or 3): Peer assessment of student project deliverables. Comparison, evaluation and feedback of ideas and artefacts produced. Encourage better presentation and audience attendance and participation. Improve (perceived) equity of assessment. Unlike in COMP340, the object of peer review was the project deliverables. We also intended to incorporate the keypads into tutorials as lecture sizes were expected to be around 100, and we only had 40 keypads to trial the technology. At third year level we do not see value in multiple choice or true/false questions that are simply at the right/wrong or mark focused level. Instead our goal was to pose questions that don't have a fixed answer or which are unanswerable on their own because more information is needed, more along the lines of template 2. See the sample questions proposed by Steve Draper[vi] relating to the learning of statistical concepts. The goal of posing such questions is to challenge thinking on the topic, to present alternative views, to explore why something would be right or wrong, determine what data/knowledge is missing, etc. The sequence would be: pose a question, get individuals to respond, display results, invite individuals to speak to why they chose that response, if needed, lecturer discusses the merits/shortcomings of each answer. A followup question can then be asked to test whether the key "right" concept/s were acquired by the majority. This approach uses the "Peer Instruction: Mazur Sequence.[vii]

Another alternative is the Class Wide Discussion: Dufresne (PERG) Sequence where a question is posed and small discussion groups are formed. The groups or individuals then vote on the question. Given that discussion has taken place, it is more likely that students will have a clearer idea in their mind why they chose that option, or each group can be asked to defend their answer. The lecturer can clarify concepts as they are discussed and correct where appropriate. We found that this technique did assist with discussion, but the technology to some extent was a gimmick and not worth the effort of setting up. Also, given that the students were working in teams and also as a unit whole focused on solving the same industry-based problem but offering alternate solutions, the need for anonymity was not so important.

The major use of the keypad in this unit was for peer assessment of other group's solutions. Demonstrating a system to a lecturer is different to presentation before your peers. In such sessions, the lecturer sat back and let groups ask the demonstrating group for justification of why a certain design choice had been made or explanation of how something worked. This was a very valuable exercise. While the same exercise could have been conducted without the keypads, the fact that you were being anonymously graded by your peers encouraged greater engagement and commitment to the process. Banks (2003) reports the use of keypad-based technology to capture and process more fine grained and meaningful data about individual team members and its presentation to the group. In the approach, the staff member leads a discussion about ways to remedy problems that have been identified. Banks notes that, while finding out what others think of you can be humbling and even hurtful, students have found that they are better able to modify their behaviours according to the groups' needs. Anonymity of individual scores can be maintained to encourage honesty and freedom of opinion. However, in 2005 and 2006 we did not receive the number of enrolments we had anticipated and thus only had less than 10 teams in each year to manage and have thus not incorporated the ideas of Banks at this stage.

PHYS270 – Astronomy

Student Population: >20 students, primarily 2nd year students from a variety of backgrounds including science, physics and education, also 1st year students from the astronomy stream.

Unit Description: This unit is a foundation course in astronomy suitable for aspiring physicists/astronomers and non-scientists alike. No prior knowledge of astronomy or physics is required as PHYS270 gives a broad underpinning of basic astronomical subjects and concepts with the essential mathematical content. A diverse range of astronomical topics are covered, starting with the solar system and then moving on to galactic stars, nebulae, galaxies, quasars, black holes and basic cosmology. The unit has a large experimental component including a night session at the division's observatory.

Keypad Technology Learning Outcomes (template 1 only): Test current knowledge at start of course, providing two-way feedback. Revision sessions at the end of semester as exam preparation.

In PHYS270 the keypads were used early in semester one, 2006 to assess the students' prior knowledge of basic astronomical concepts. The questions used were taken from a number of multiple-choice "pretest" question sets found on the internet, and addressed various topics such as the phases of the moon, concepts of gravity, astronomical distances and simple cosmology. These were used to identify areas where the students' general knowledge was particularly weak, so that these topics could be properly emphasised in the lectures. The students were also asked a number of demographic questions in order to discover their level of mathematical competence, their confidence in their ability to study maths and science and their expectations of the course.

At the end of this session, the students were asked their opinions on having used the keypads, using a five point likert scale. Their responses indicated that:

- They enjoyed using the keypads (3.6);
- They believed the keypads could be useful as lecture tools (4).

A number of students gave negative responses to the first question, as they were concerned that use of the keypads would take time away from lecture material.

Due to time constraints, our plans to include keypad use during lectures never materialised, although material is currently being prepared for semester one 2007.

In the last week of the semester, the final three classes were dedicated revision sessions, using the keypads (in anonymous class feedback mode) to ask the students multiple-choice questions on the material previously covered in class. A typical revision session asked 20 questions in an hour, giving the lecturer time to discuss and correct any lingering misconceptions and explain to the students why they may have chosen the wrong answer. The questions were taken from the accompanying material to the textbook, and were chosen to closely correlate with the coursework and with past exam papers.
At the end of the revision work we asked the students a series of questions about using the keypads in future classes using a five point likert scale. They responded that:

- They enjoyed using the keypads (4.35);
- They would find it useful if the keypads were used for revision of key points at the start of lectures (4.37);
- They would find it useful if the keypads were used to introduce topics during lectures (4.4);
- They would find it useful to do assessed multiple choice questions throughout the semester (in moderation) (3.25).

Comments were sought from the students and the general consensus was that the keypads were "cool", but that they should have been used more during the semester.

Incorporating automated response systems into teaching

In order to employ the keypad technology, we followed the following iterative process:

- **Analysis/consultation** with the academics involved in teaching the unit. Discussions concerned presentation of what the technology looks like and how it works; possible uses and previous uses in the literature; what content, if any, was appropriate; what type of assessments were being performed and how the keypad could assist; class sizes and how to handle if there were more than 40 students since we only had 40 keypads; where, when and what type of feedback was most important for that unit. Depending on the interest and commitment of the lecturer and the perceived value of the technology, key units were identified for inclusion of keypad-based technology.
- **Design** the modules/quizzes for the selected units. For example, how will quizzes be run, how will feedback be provided, what will the role of assessment be? Use of the technology for assessment should be more limited at first as this may require redesign of the unit and will be of greatest concern to the students. Our focus for pilot usages was on demonstrating to students and lecturers how the technology can be used and, in the case of the latter, training them to apply it for themselves. Given that some slides do not contain course content, such as peer assessment slides that capture a score, such slides could be stored in a shared repository for use by any lecturer interested in such a resource. However, setting up slides is so simple, we doubt that the effort involved in maintaining a bank of

such generic slides would be of value. There is, however, value in using questions from prerequisite units that could be stored in a shared question bank at the start of the follow-on unit to assess student competence and whether catch-up lectures are needed.

- **Development, deployment and maintenance** of the presentations according to the outputs of the analysis, design and/or evaluation phases. This phase requires following the user guide to perform such tasks as: selecting the appropriate slide format, filling in the fields, selecting what results are required and how the results will be displayed, preparing report formats, adding a timer if required, configuring the devices. This phase also included using the Powerpoint presentations and collecting relevant data about student responses. We include maintenance in this phase as presentations will need changes when improvements are identified or errors detected.
- **Evaluation** of the technology usage against a set of predetermined criteria. The most obvious criteria are the learning goals. In this technology, evaluation can be instantly provided. For example, as soon as students enter their responses via the keypad the teacher can display the results. Reports can be easily produced with questions linked to learning outcomes that indicate when most of the class have achieved competency. Other criteria which require more detailed and longer-term evaluation include: return on investment; increased attendance/participation; improved marks in assessments and pass rates.

While it is desirable to see improved learning and higher results achieved by students in the units using this technology, it would be very hard in the short term to make any valid claims linking improved performance with the technology. However we believe that strategies such as mid term tests are very valuable forms of timely feedback to teachers and students and that this technology should be able to allow us to conduct such tests which have tended to become too labour intensive to administer. We could expect to see over time, with the (re)introduction of tests, assessable and non-assessable, and increased student engagement and motivation, that overall results would improve.

At this stage what we have reported are results from a couple of lightweight surveys regarding satisfaction and various anecdotal evidence. We have not conducted trials aimed at providing evidence of return on investment in terms of increased student satisfaction/improved learning outcomes, more timely feedback and reduced marking costs. On the latter point it is easy to calculate the number of marking hours saved where existing assessments are being replaced since that data is already collected. However, the problem is that we have mostly introduced additional tests that are not currently funded, e.g. peer assessment marking and adhoc tests. Also, we have used the technology to support fulltime academics who do not directly pass on costs of individual tasks they perform in teaching a unit. Further, in evaluating teaching methods it is not possible to treat students differently and have a control group which is not taught using the new method, unless the differences are reversed or resolved by completion of the unit. While some claims could be made based on improved scores of a cohort, it is difficult to be definitive about the causes of such improvements. Dissemination of our findings, as provided in this paper, is also part of the evaluation we have performed.

Discussion and future directions

Lecturers typically try to encourage interaction with students in lectures/tutorials but without real feedback in both directions it is difficult to determine if the ideas are coming across. Studies using keypad-based technology are often motivated by the need to assess each individual's understanding or viewpoint and the realisation that quite often there are only a few in the group that really understand what is being said. The others have become disengaged. The main problem identified in large classes in large lecture theatres is usually the lack of interaction which results in extreme passivity rather than active learning (Draper, Cargill & Cutts, 2002). In support of these findings, at a recent Computing 300-level liaison meeting, students informed us that the number of friends you have has a big impact on your likelihood of success in assignments and tutorials (this goes beyond plagiarism issues which we are actively seeking to control and minimise). Relying on friends becomes a mind set where a few bright students identify the key parts of the solution and others simply need to work at the more concrete level implementing their ideas. To counteract plagiarism, the Computing Department relies heavily on final exams for assessment but this results largely in testing how well the text book can be memorised and does not test who is competent in applying the concepts. From an industry point of view, this is unacceptable and delivers students that will not be valuable employees. Using the keypads requires students to pay attention in lectures and think about the content for themselves. In this respect, this technology has the potential to significantly change the character and capabilities of the students we graduate.

A technique that the author has been using for a number of years in lectures is to get students to solve a problem on paper and to hand in the solution for review. In a subsequent lecture or tutorial, students are shown many of the models developed, including good and bad examples. This approach has been particularly used for concepts that large numbers of students continue to get wrong. It seems that seeing your own examples and various other counterexamples does a great deal to break long term conceptual errors that have occurred through shallow and rote learning which are encouraged by summative assessment approaches, for example end of semester final exams. Formative assessment, in contrast, is "low stakes and low stress…the focus is not on the 'right' answer, but on the distribution of answers and the reasoning behind each one" (Dufresne et al., 2000). Ongoing use of the keypads allows us to assess throughout the course how the students' understanding is developing and where the weak spots are. We found that getting the "right" answer was often not the point, but that opening up discussion of how different problems, concepts and ideas could be interpreted got people talking and thinking.

We would like to explore further the idea of Su (2003) of getting students to develop multiple choice questions for other individuals/groups as it means that students must first identify key learning concepts themselves, identify the nuances between various solutions, the approach is collaborative and the burden of preparing questions is passed on to the students making the technology more tenable for adoption. We suggest that the overhead involved in preparing problems in problem-based learning is probably the key reason why problem-based learning is not used more widely. However, we are unsure whether first or second year students have the maturity to develop quality questions. At third year level and above we are unsure whether multiple choice or true-false questions are so relevant. Despite our reservations, in the future we would like to explore this possibility, perhaps in tutorials.

The key limitation we found with using the keypads concerned the logistics of carrying, setting up, distributing and collecting the physical equipment. We envisage that if the university perceives value in using the technology the TurningPoint software will be purchased and installed on all lectern computers, a receiver will be installed in all lecture theatres and that each student would purchase or be given a keypad at enrolment at a cost of around $5 per student. This keypad could be registered to the student and used in whatever class the student attended. However, the set up and support of this infrastructure would be a considerable cost to the university. With a view to the future, Russell and Pitt (2004) suggest the following possibly more practical wireless solutions:

- Personal digital assistants (PDAs) with basic infrared (IR) connectivity;
- Cell phones using wireless application protocol (WAP);
- Cell phones capable of downloading Java applications;
- Pocket PCs like the Hewlett Packard iPaq;
- Cell phones that also include wireless local area networks (WLAN).

We expect that in the not so distant future that these solutions will have software and hardware to support them. At that stage, the technology should be accessible to any teacher or student who wants to have some fun while they get essential feedback.

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Acknowledgements

This project has been funded via a Macquarie University Teaching Development Grant and the Division of ICS.

Author contact details

Debbie Richards, Department of Computing, Macquarie University, NSW 2109, Australia.
Email: richards@ics.mq.edu.au.

Catherine Braiding, Department of Physics, Macquarie University, NSW 2109, Australia.

Alan Vaughan, Department of Physics, Macquarie University, NSW 2109, Australia.
Email: alanv@physics.mq.edu.au.

[i] http://www.educue.com/interwriteprs.htm
[ii] TurningPoint is a product of Turning Technologies, LLC. Portions Responsive Innovations, LLC and Microsoft Corporation.
[iii] We have been using devices produced by KEEpad http://www.keepad.com
[iv] http://library.cpmc.columbia.edu/cere/web/facultyDev/ars.cfm?cat=facultyDev&pgNav=ars
[v] http://www.psy.gla.ac.uk/~steve/ilig
[vi] http:www.psy.gla.ac.uk/~steve/ilig/feedback.html
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