

Using Tablet PCs For Active Learning: Learning From Others' Mistakes

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Tablet PCs were used interactively in a Discrete Mathematics course in the first year of a Computing degree. The main benefit expected was an improvement in student engagement, but peer instruction was very evident and the ability to display many student answers led to very effective and immediate feedback, particularly when incorrect answers were displayed to the class. We discuss our experiences and the student reactions, and in particular, what they reported as the main advantages.

Tablet PCs were used in a course on Discrete Mathematics in the first year of the Bachelor of Information and Communication Technologies at CPIT (Christchurch Polytechnic Institute of Technology) in New Zealand. This one-semester course has two sessions per week, each of two hours. Before we used tablet PCs, each class session consisted of a one hour lecture followed by a one hour tutorial. During the tutorial, students worked on exercises related to the content of the lecture. The mathematical background of students varied widely from those who had studied mathematics at university to those with low Mathematical Self Confidence as measured by the Betz MAS (Pajares & Urdan, 1996) and Marsh SDQIII (Gourgey, 1982) tests.

It is generally recognised that the traditional lecture format is a passive learning environment which is not conducive to learning (Chickering & Gamson; Fister & McCarthy, 2008; Guthrie & Carlin, 2004; Knight & Wood, 2005). Certainly that was our experience. Within the traditional lecture format it is possible to ask questions of the class but usually it is only one or two students who are prepared to volunteer an answer. Now that we use tablet PCs, each class session consists of a two-hour class in which mini-lectures are interspersed with exercises on the tablet PCs.

We were aware that research suggests that media does not affect learning (Russell, 2006) so our aim in using tablet PCs was to enable the engagement of all students. Learning in general, and mathematics in particular, requires students to practice what they have learnt. Again our aim was to use the tablet PCs for active learning (Anderson et al., 2007) and we expected engagement by most students (Guthrie & Carlin, 2004).

Literature Review

People learn, and in particular learn mathematics, by doing: by building on their existing knowledge, by explaining their understanding, their ideas, their solutions, their progress, by receiving immediate feedback, by interaction with peers and the lecturer, and by active learning (Anthony, 1996; Knight & Wood, 2005; D. A. Smith, 2002; Zepke & Leach, 2010).

Student engagement is a major factor in student achievement (Zepke & Leach, 2010). Student engagement is encouraged by active learning, co-operation among students, peer instruction, and student/faculty interaction (Chickering & Gamson; K. A. Smith, Sheppard, Johnson, & Johnson, 2005). D. A. Smith (2002) advocates, among other innovations for teaching mathematics, the use of technology to enable: learning by doing, students to

receive feedback, and co-operative learning. Using tablets for teaching can allow students to: discuss solutions with others, display their work, and explain their results (Anderson et al., 2006; Fister & McCarthy, 2008). Using tablets enables many of the principles of good practice in undergraduate education (Chickering and Gamson), in particular active learning and prompt feedback. Mazur used challenging multi-choice questions in conjunction with clickers to promote engagement. After answering the question the students then explained and discussed their thinking with their neighbour which promoted further engagement and also peer instruction (Mazur, 1997).

When using clickers or tablets the use of technology helps significantly to overcome students' reluctance to answer questions (Crouch & Mazur, 2001; Freeman, Blayney, & Ginns, 2006; Razmov & Anderson, 2006). Using tablets in pairs almost guarantees discussion among students and peer instruction. Also, most importantly, the use of tablets allows for students to not only submit their answer but also an explanation for that answer. Producing an explanation, right or wrong, is a powerful learning step and it enables the lecturer to provide more useful, constructive feedback (Anderson et al., 2007; Anthony, 1996; Draper, 2004; Schacter & Fagnano, 1999). Producing an explanation plus discussion allows for peer instruction. A student who understands can explain in student-centred language to a fellow student. And they both learn (K. A. Smith et al., 2005). Using tablets allows for anonymous student submissions and immediate feedback to the students who make the submission as well as comments and discussion that the whole class can learn from (Anderson et al., 2006; Razmov & Anderson, 2006; Roschelle et al., 2007).

Using Tablet PCs for Active Learning

We began our lesson planning by choosing a pedagogy that suited the use of tablet PCs. Peer instruction is such a pedagogy and Mazur (Crouch & Mazur, 2001) developed ConcepTests which applied this pedagogy to learning activities. Mazur's ConcepTests involved students answering multi-choice questions using clickers and then discussing their answer with their neighbour. Tablet PCs are more versatile than clickers as students can write, draw and type answers in addition to selecting multi-choice answers, and we modified the sequence of events in Mazur's ConcepTests to suit activities in which students use tablet PCs in pairs. It was a complete turn-a-round from the lecturer doing all the work to the students being asked to do multiple problems each session.

The tablet PCs were used at appropriate times in each class lesson. The lecturer, whose tablet PC was connected to a data projector, introduced a concept and then sent a question to the students' tablet PCs via a wireless network. Students worked in pairs on a tablet PC that had Classroom Presenter (Anderson et al., 2006) installed. They wrote their answers on their tablet PC using the electronic pen before submitting them anonymously to the lecturer. Next, the lecturer displayed a selection of students' answers to the class with the data projector. Answers, both correct and incorrect, were selected so that a variety of solution strategies and common errors could be discussed. During this discussion, the lecturer annotated the student answers. Students could then correct or add notes to their own tablet PC answer as a result of their learning during the discussion and then save it for later study. This sequence of steps which is repeated for each learning activity is summarised in Figure 1.

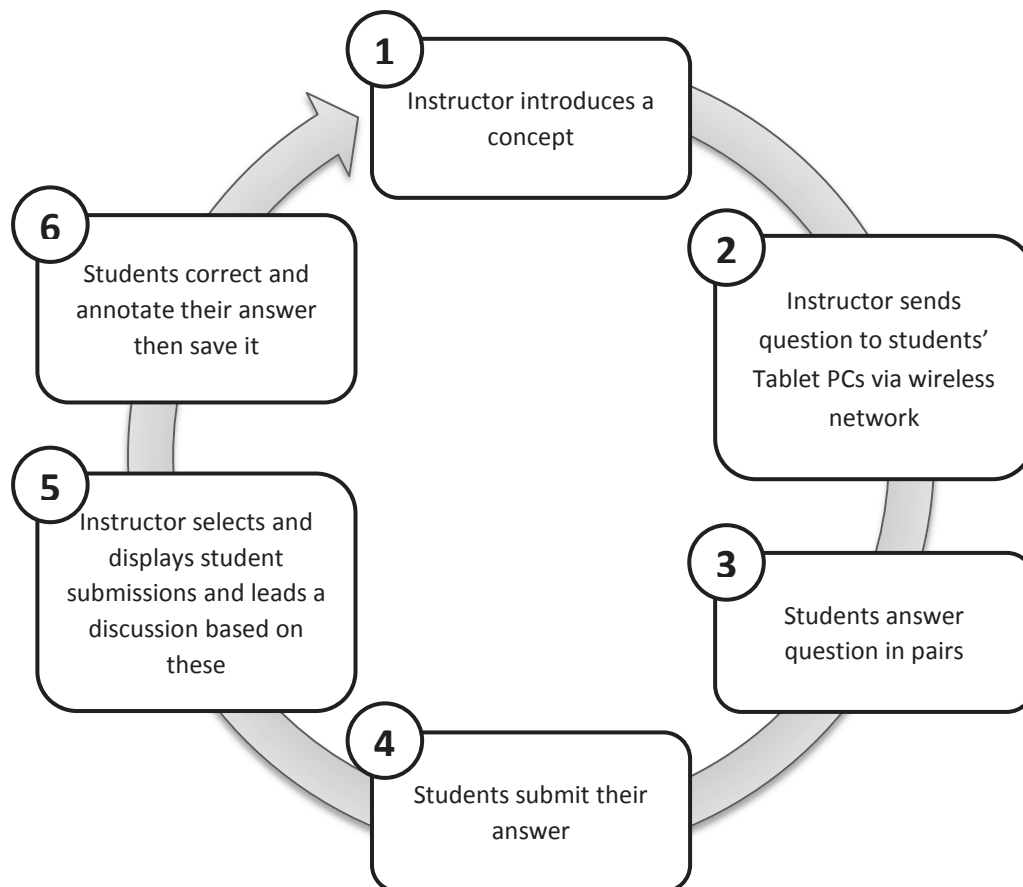


Figure 1. Activity sequence for interactive learning activities.

In order to use the tablet PCs interactively in this way, we wrote a set of questions for each lecture. Each question concentrated on just one concept or topic and our expectation was that most students would be able to complete them. We followed the guidelines for digital ink (Anderson, Anderson, & McDowell, 2005) and designed questions so that there was enough room for students to write and the finished answer wouldn't be too cluttered. The amount of space inside a diagram or table was important and we found that providing a clear structure for the answer made it easier for students to answer the question and to follow other students' answers when they were displayed to the class. The Mazur ConceptTests approach is designed for use with clickers and based on multi-choice questions. A distinct advantage of using tablet PCs is the range of questions that are possible. We wrote a range of different types of questions, for example: complete a table, compare solution strategies, find the mistakes, draw a diagram, and write symbols or text. We often found that a particular concept was best suited to certain question types. Examples of our questions are shown in Figure 2.

Before using the questions with students, we tested the questions by answering them on a tablet PC ourselves. This led us to make changes such as creating more room, splitting a question into two or reducing the amount of writing required.

Write the Boolean expression

a) Colour the area represented by $\overline{(A \cup B)}$

b) Colour the area represented by $\overline{A} \cap \overline{B}$

c) What law does this illustrate?

Idempotent Commutative Associative Distributive De Morgans

Convert 164_{10} to binary.
Truncate your answer to 6 binary places

2)164	rem

.1	x 2

Answer =

Correct the errors

$$\overline{ab}(a + \overline{b})$$

$$= (\overline{a} + \overline{b})(a + \overline{b})$$

$$= a\overline{a} + \overline{a}\overline{b} + ba + b\overline{b}$$

$$= 1 + \overline{a}\overline{b} + ba + 1$$

$$= \overline{a}\overline{b} + ba$$

$$= \overline{a}\overline{b} + ab$$

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Figure 2. Examples of questions.

Methodology, Data Collection, and Evaluation

The change from traditional lecture delivery to active learning using tablet PCs was conducted as an action research project with the main aim being to enable student engagement. For the first semester when tablet PCs were used one lecturer sat at the back of the classroom as an observer and noted what seemed to work, what changes were needed, how students responded etc. Each week the two lecturers involved met to discuss and reflect on the sessions and make changes as required e.g. some questions were too long or too difficult, and a revision question (based on the previous session) was introduced.

A questionnaire was developed to collect students' perceptions of this use of tablet PCs. Some questions simply required an agree/disagree response e.g. Easy to use, Enjoyable, Helped my learning. Other questions were open-ended e.g. What were the advantages and disadvantages of using tablet PCs for learning? Others used a five point scale from very unhelpful to very helpful and included an area for additional comments.

Towards the end of each one-semester course, the students were asked to complete the questionnaire. Questionnaires were completed by 58 of the 72 students in this study. The other 14 students who did not complete the questionnaire were either absent, chose not to complete it, or were no longer attending the course. After categorising and counting the advantages and disadvantages listed by students, the students' perceptions of the main impacts on learning were identified. To complement the student data, the lecturer and the observer recorded their own reflections throughout the course.

Results and Discussion

We were very pleased to observe that students were excited about this pedagogy. When a question was sent to their tablet they would discuss it in their pairs and sometimes with others around them. And they were interested in the lecturer-led discussion of submissions.

In completing the questionnaire students recorded many advantages and a few disadvantages. In the next two sections, we consider those mentioned most often and discuss relevant reflections from the lecturers.

Advantages of using tablet PCs

Students were asked what advantages they found for learning from using tablet PCs in class. This was a very open question and the questionnaires were completed individually with no opportunity for consultation with other students. Therefore all advantages listed were a result of students' individual opinions of the impact of using tablet PCs on their learning. Most students listed at least one advantage and on average, students wrote two advantages. These were put into categories and summarised in the following table.

Table 1
Advantages of using tablet PCs as reported by students

Advantage reported	Number of students (n = 58)	Percentage of students
Viewing, discussing and receiving feedback about students' answers.	26	45%
Easier or faster to learn or suited learning style	25	43%
More interactive	23	40%
More fun, interesting or enjoyable	22	38%
Other	20	34%

Viewing student answers

Nearly half the students described advantages of seeing other students' answers and the associated lecturer led discussion, for example:

"Going through the answers let me see both my mistakes, and other possible mistakes and problems, and how to correct them."

"Often you learn more from understanding mistakes"

"Can see, share, and learn from other's answers"

"Immediate feedback to students without great cost of tutor's time."

"Anonymity – not worried about being wrong."

In our discussion of the questionnaire analysis we felt this was the most important impact that using tablet PCs had on learning. Using tablet PCs meant that all students could see all the student answers, and especially incorrect answers, that the lecturer displayed to the class. It was also a way of obtaining responses from many students, not just the one or two who always answer questions. Displaying incorrect answers and asking "What went wrong here" made deeper learning possible. We noted that students often submitted a second answer when they realised their first answer was wrong – another valuable learning experience. Thus, students saw various errors and their consequences, as well as a variety of strategies for solving problems. In addition, students received lecturer feedback about all of these.

We also appreciated being able to adjust our lesson plans as a result of seeing the overall understanding of students in the class. In some cases, all pairs of students submitted correct answers and we could confidently move on to the next concept. In other cases, it was clear to both lecturers and students that more time needed to be spent on a particular concept.

As lecturers, we felt that viewing and discussing student answers caused the learning to be more memorable. It also meant that students made a more valuable contribution to lessons. Using tablet PCs was a way of involving students in active learning, especially quieter students and those who speak English as their second language, with reinforcement of the concept just presented and immediate feedback on their understanding.

Peer instruction

Students recognised the advantages of working in pairs and there were many positive comments about working with other students, for example:

“Working with a partner meant if one did not follow as well, the other could help out.”

“As I explained concepts, I understood more clearly what I was learning”

“Opportunity for students to problem solve co-operatively.”

The peer instruction was more evident than we expected and was also important to the students. When a problem was sent to the student tablet PCs most pairs would discuss the problem, and some would refer to their notes or to the textbook.

Conclusion and Comments

We chose to use tablets for engagement and active learning – and that certainly occurred. But peer instruction occurred and also learning from seeing others’ submissions and others’ submissions discussed – especially the submissions that were wrong. Before embarking on the project we had mixed feelings about the potential of tablet PCs to impact on students’ learning. We were aware of the results of many research projects which concluded that media does not affect learning, but we could also see the potential for tablets to improve students’ engagement with learning activities during class and expected this to be the major benefit. We did not actively promote Mazur’s peer instruction method, i.e. justify your answer to the student beside you, because we were not using multi-choice questions and displaying aggregated results. Our use of tablet PCs indicated two other major benefits for student learning in addition to active learning and engagement.

Firstly, working in pairs with a tablet PC led to very effective peer instruction. We found, as described by Draper (2004) that the important component of peer instruction is providing an explanation for the answer. Sharing a tablet PC encouraged discussion and explanation of answers. As noted by Roschelle et al. (2007) using tablet PCs provides a richer peer instruction environment and that was our experience too.

Secondly, the ability to display students’ anonymous answers to the class led to students receiving relevant and focussed feedback. Students received feedback on their own answers and those of others and, as recognised by the students in their questionnaire responses, the students’ answers became a very important part of lessons. The lecturer provided feedback and led meaningful class discussion on a wide variety of answers. These could be correct, use an alternative solution strategy, or be incorrect, but it was the mistakes that often led to the most interesting discussions. These results support Anderson’s (2006) comment that it is best to display an incorrect solution for discussion before displaying correct solutions. Student comments indicate that seeing other students’

submissions, both correct and incorrect, and the lecturer comments was very helpful for their learning.

We agree with others that the use of tablet PCs allows for richer interactions both with peers and with the lecturer and note that this is particularly true of incorrect answers, explanations, or methods. Seeing others' submissions, and their mistakes, and then discussion of these submissions provides feedback to those who make the submissions and also learning for all students.

We expected the use of tablet PCs to promote student engagement and enable active learning. But an important impact, identified by the students, of using tablet PCs, because it is so difficult to achieve in any other way, was that seeing other students' work, especially their mistakes, helped students learn.

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