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The use of tablet and related technologies in mathematics teaching

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According to *Standards of Excellence in Teaching Mathematics in Australian Schools*, excellent teachers of mathematics need to create “an environment that maximises students’ learning opportunities”; so that they can encourage self-directed learning, “model mathematical thinking and reasoning”, and provide “purposeful and timely feedback” (Australian Association of Mathematics Teachers (AAMT), 2008, Sec 3). In the last ten years new technologies have provided teachers of both school and university mathematics with more opportunities to approach such excellence. The Tablet PC and associated technologies together provide one such opportunity.

A Tablet PC is a laptop computer, equipped with a touch-screen and a stylus to enable the user to write on or manipulate the screen. While Tablet PCs have been available in education since the beginning of this century, costs and perceived difficulty of use has meant that their full potential has rarely been investigated. In universities teachers have used them to enhance their lectures in engineering, mathematics, computing and chemistry (e.g., Al Zoubi, Sammour & Al-Zoubi, 2007; Kohorst & Cox, 2007; Loch, 2005; Loch & Donovan, 2006; Olivier, 2005). In the classroom, Wise, Toto, and Lim (2006, p. 20) claim that the Tablet PC “is an easily-adopted technology that can have positive effects on student attention and learning”. In distance education Tablet PCs have also been shown as useful facilitators of communication with remote online students, allowing both teachers and students to use electronic handwriting to give and receive knowledge and skills (e.g., Loch & McDonald, 2007). From survey results, the perceptions of digital ink technology, Reins (2007) suggests that when students use Tablet PCs they become an integral part of the lesson, while Tutty and White (2006) argue that the Tablet PC classroom environment is “more effective than the traditional format of lectures/tutorials/practicals [and that this is] in part due to the increased emphasis on the social aspects of learning and the processes students undertake when meaning making” (p. 4). Philip (2007) in a reflection on the practices of Net Generation students, believes that as student education becomes virtual, this change promotes the use of “thinking prosthetics and continues to transform student expectations of their learning environments” (p. 2).

Harris, Mishra and Koehler (2009) in their technology, pedagogy and content knowledge framework, propose a way of thinking that includes the critical role of context in the effective integration of the technology. For instance, the mathematical disciplines rely heavily on the use of symbols and graphs where the teacher traditionally writes or draws by hand to explain mathematical concepts step by step to students. The unique features of Tablet PCs, graphics Tablets or digital pens allow the user to easily write symbolic and graphical information electronically, and provide the teacher with a tool to explore different paths to a solution, or to adjust a lecture based on audience reaction (Loch & Donovan, 2006).

This paper details some of the ways Tablet PCs and related technologies have been used to foster good teaching and effective learning for students in the early years of university study independent of whether they are in large groups, small groups, in individual consultation situations, in classes or remote from a teacher in distance learning situations. It will focus on the teaching of one-to-many, one-to-few and one-to-one, addressing “stuck places” and online synchronous teaching drawing from investigations and research conducted by the authors since 2004.

Background

The University of Southern Queensland (USQ) is a large distance education provider in eastern Australia with 80% of its 26000 students studying by distance or online education. USQ supports high levels of flexibility in its programs of study by ensuring that students have opportunities for equitable learning experiences no matter where or when they are studying. Building on this flexibility, Tablet PCs and related technologies allow new and faster delivery and communication methods for mathematics teaching. This means that for online and distance education, student learning experiences can go beyond simple text formats to all symbolic and graphical alternatives to be rapidly built and disseminated. The authors commenced research into the usability and functionality of Tablet PCs in 2004 when Tablet PCs and graphics Tablets (a USB-connected device with a stylus to enable the user to hand-draw or write on the screen) were used to teach large lecture groups of students studying first year mathematics. In late 2006, USQ funded a project to further investigate their potential in large mathematics and statistics first year courses offered on-campus and at a distance. In 2007 the project was extended beyond mathematics teaching and the research has to date involved a total of 10 staff, including the disciplines of Engineering, Chemistry, Biology and German language. This paper focuses on the mathematical sciences with over 2000 students involved in Data Analysis (DA), Discrete Mathematics (DM), Foundation Mathematics (FM), Operations Research (OR), Algebra and Calculus (AC) and Building Professional Nursing Attributes (Numeracy) (NN), using Tablet PCs, screen capture and virtual classroom software to:

- record and disseminate lectures;
- engage and record students in tutorials;

- capture video snippets of difficult concepts for later distribution;
- conduct one-to-one consultations when student and teacher are geographically distant; and
- conduct small group problem solving sessions with students located across Australia.

With each course, evaluations were undertaken via student surveys and formal student course questionnaires.

The following section focuses on the application of Tablet PCs and related technologies in teaching face-to-face and at a distance. Three situations are described: the lecture (teaching one-to-many), the tutorial (teaching one-to-few), and consultations (teaching one-to-one). Examples and preliminary results of the authors' research in staff and student satisfaction and reflection of their impact on learning are presented. The advantages and disadvantages of the technologies in these settings are listed.

The lecture: Teaching one-to-many

Teaching mathematics in schools and at university often requires the teacher to write solutions to problems on the board so that students can see the expert's approach to solving a problem. At university this lecture mode of teaching is still common. Traditionally in mathematics, lectures are given by either writing directly on a whiteboard or using an overhead projector. Production of PowerPoint slides in mathematics is possible but time consuming and allows little flexibility when problem solutions are prepared before class, not allowing modification in class. Tablet PCs with their capacity to create electronic handwriting can transform the lecture experience. Teachers can now face a class, display questions and step by step solutions clearly to all students, respond quickly to unplanned student questions and most importantly record all details of a lecture using screen capture and voice recording software.

How the Tablet PC is used in the lecture at USQ

Exploration of electronic writing in mathematics classes commenced at USQ in 2006 with trials in two subjects to support the presentation of a lecture (Foundation Mathematics and Algebra and Calculus). The tablet technology was also used to record lectures in Foundation Mathematics with the software *Camtasia Studio* (<http://www.techsmith.com>), edited, and rendered to formats that could be delivered online or via mobile device. Figure 1(a) shows a lecturer writing on the Tablet PC in a large lecture theatre, while the Tablet PC made it possible to capture two pathways to a proof (Figure 1(b)) following a suggestion by a student in a lecture.

When the lecturer is writing solutions to problems, students can see the solving as it occurs. They can hear the explanations step by step. However, once that is done it becomes a static object similar to text book explanations. Much of the learning potential is lost. A Tablet PC with the aid of editable screen video and voice capture can record the solving of a problem with the

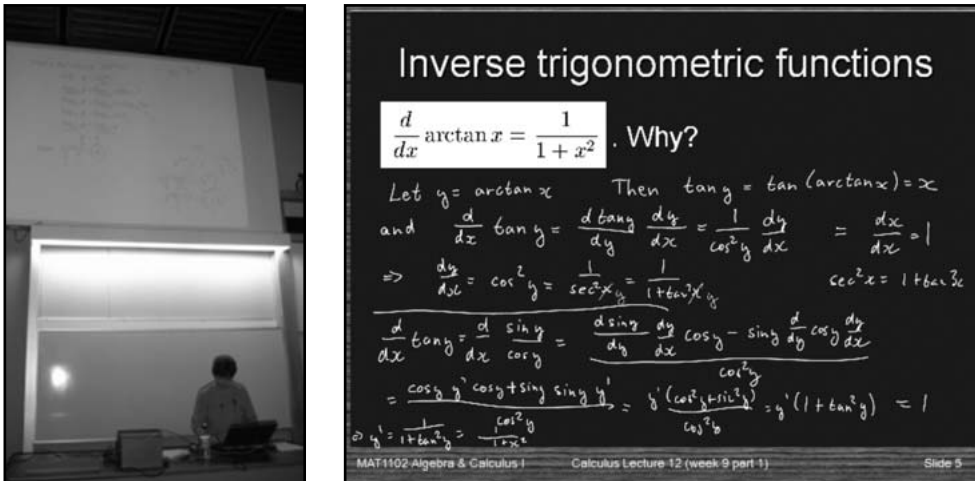


Figure 1. Lecturer using a Tablet PC in a Foundation Mathematics lecture (a) and screenshot of an Algebra and Calculus lecture slide (b).

lecturer’s explanations as they are writing (see Figure 2). Such software captures anything that is displayed on the screen, so lectures containing video, internet sites and simulations can easily be included and recorded. In 2008, lectures in the first year subject Operations Research (on-campus and distance education) were recorded and made available to all students via the university’s Learning Management System. Contrary to the popular belief of many university teachers this did not decrease the on-campus class attendance. In fact students commented that they came to class for the interaction, and the chance to ask questions.

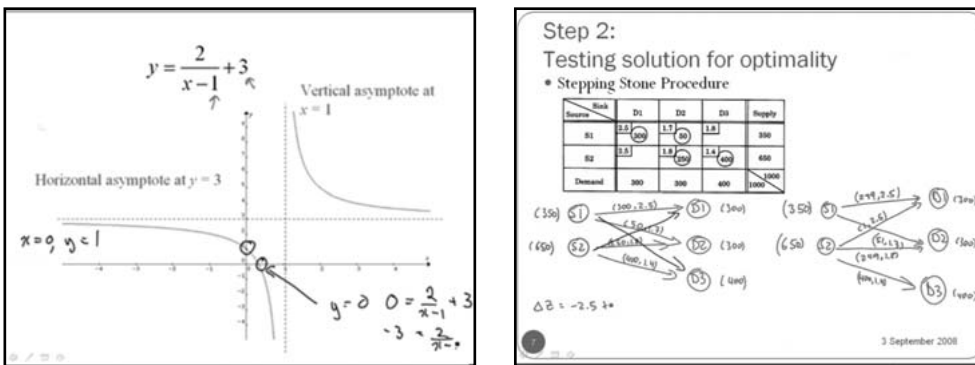


Figure 2. Screen shot of a frame from a mathematics lecture recording: Foundation Mathematics (a) and Operations Research (b).

Student feedback on lectures

When students attending the face-to-face lectures in Algebra and Calculus were surveyed on the use of Tablet PCs in lectures, 54 students responded (from 120). Seventy-five percent of them said they preferred the lecturer to write on a computer and 98% said writing during lectures helped their understanding. Even better results were obtained in Operations Research when 9 out of 13 students responded to the survey and all agreed that writing during lectures helped their understanding.

In a further evaluation, 23 Foundation Mathematics students in the lecture were surveyed and all student responses were overwhelmingly positive. Most students commented on the visibility of the handwriting and annotations of the PowerPoint slides on the large screen, although this was qualified by comments that encouraged the lecturer to ensure their handwriting was legible.

In this same course, 15 distance education students were sent a CD of a group of five lectures and similarly asked to comment. The main responses were associated with the ease with which the material came alive for them through voice and screen capture of solutions in action. They also commented on the advantage of having such lectures for later revision.

Typically, student comments included:

[U]sed them mostly as revision. I often paused the lecture when a new problem was displayed, solved the problem and then played the lecture to see if I was correct. I found this useful as there were some problems not in the printed study materials (FM on-campus student).

It's easier to understand a lecturer, as you get the information portrayed as well as explained in a lecture context. Most of the questions that I had were also explained. The other point for me was that I was able to pick up vital information during lectures that is summarised well by the lecturers, sometimes explanations which cannot be made in a book (FM on-campus student).

To be honest, without these online screencasts, I would not have understood concepts or passed this course (OR distance student).

I wasn't able to attend all of the lectures so this allowed me to go at my own pace (OR on-campus student).

It was apparent from the above comments that not only does the recorded lecture provide real time modelling of mathematical thinking and reasoning, it also provided more opportunities for self-directed learning. Table 1 summarises the advantages and disadvantages of using a Tablet PC when teaching one-to-many.

Table 1. Advantages and disadvantages of using the Tablet PC in a lecture.

Advantages	Disadvantages
<ul style="list-style-type: none"> • Lecture is easy to see and understand • Allows revision for all students • Allows lecturer to respond easily to students' questions whilst keeping a record • Allows post lecture reflection on difficult points • Explanations are clear and more personalised for distance students 	<ul style="list-style-type: none"> • Clear handwriting is still required • Complex solutions can get messy • Technology may not always function properly • Set up time can be slow for inexperienced users

While it is possible to combine teaching with the Tablet PC and a whiteboard, this option was not explored at USQ as one of the aims of the project was to provide similar learning experiences to on-campus and distance students. Distance students would not have been able to access whiteboard writing.

The tutorial: Teaching one-to-few

At university, teaching mathematics in online or face-to-face tutorials can take a very traditional format in which students are given tutorial questions to solve and a tutor is there to assist when they get stuck. In classroom situations a variety of teaching approaches which encourage cooperative learning are now becoming more common. With Tablet PCs such approaches can be made more engaging and less threatening in face-to-face situations and can be attempted online when students are located remotely from each other and the teacher.

How the Tablet PC is used in online synchronous situations

While online synchronous chat has been reported in higher education as useful for more interactive and fruitful group discussions between distance learning students and their tutors (Burnett, 2003), this has usually been in non-quantitative based courses. Building on a small scale exploratory trial in 2005 (Loch & McDonald, 2007), the authors in 2006 offered online synchronous tutoring sessions in Foundation Mathematics in the evening at home through Windows Live Messenger (Messenger). In all 240 students were approached, 52 replied, 41 participated in at least one session and 20 responded to an evaluation. Figure 3 shows a sample of the whiteboard chat. At the time, Ann (the tutor pseudonym) was using a graphics tablet and students a mouse to write freehand.

USQ also trialled the web conferencing software Elluminate Live! in 2006/2007 (Reushle & Loch, 2008), when classes were offered in the subjects Algebra and Calculus and Data Analysis. The use of audio and immediate visibility

- Ann says: Ok - if you look at the graph (not logged) how can you find the equation - but if you log it and graph it - look what happens - try plotting just these three points - anyone want to roughly sketch it here!!
- Tim says: sorry, don't understand
- Tim says: make a new graph?
- Ann writes

- Tim says: righto
- Steve writes:

- Tim says: aha, I get it

Figure 3. Excerpt from an online tutorial class.

of writing on the whiteboard (as opposed to having to wait for a handwritten message to be completed and posted), changed the dynamics of the online class, putting more pressure on students and teachers as responses were expected immediately. The handwritten chat gave the opportunity to think about an answer. Tools identified by the students as most useful for mathematics teaching were: audio, shared whiteboard, graphing calculator (see Figure 4a) and typed chat for quick messages, while sharing the screen proved important when working through study material or assessment tasks or to explain code written in Matlab (a software package for algorithm development, data visualization, and data analysis). In the statistics tutorials, the shared whiteboard proved to be the most important component as all students could contribute by underlining keywords and completing steps toward a solution (see Figure 4b).

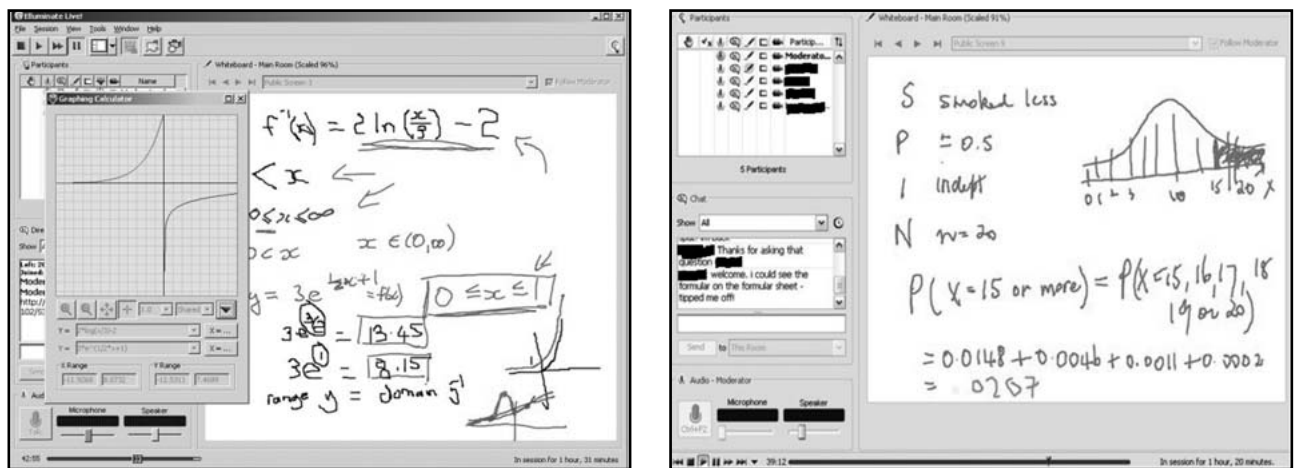


Figure 4. Screenshot of an online tutorial in Algebra & Calculus (a) (Reushle & Loch, 2008) and Data Analysis (b).

Another additional feature in the web conferencing sessions was the students' ability to watch a recording of a session, either to cover for a missed tutorial, or to revise a concept they felt they had not mastered.

How the Tablet PC is used in the tutorial

In 2007 and 2008 Tablet PCs were used in on-campus mathematics tutorials. The Tablet PC was wirelessly connected to a data projector, which enabled the tutor to move around the classroom and hand the Tablet PC to a group of students to write on the screen for all to see (see Figure 5). This wireless technology overcame a previous disadvantage of Tablet PCs where the lecturer had to be stationary (King et al., 2008).

In Foundation Mathematics, students in a class were given a set of mathematics questions on a particular topic. Each group chose a question and worked on the solution by hand. After a few minutes they were then asked to write their solution on the Tablet PC, so the class could see the solution as it unfolded (like asking the students to go to the whiteboard). The advantages

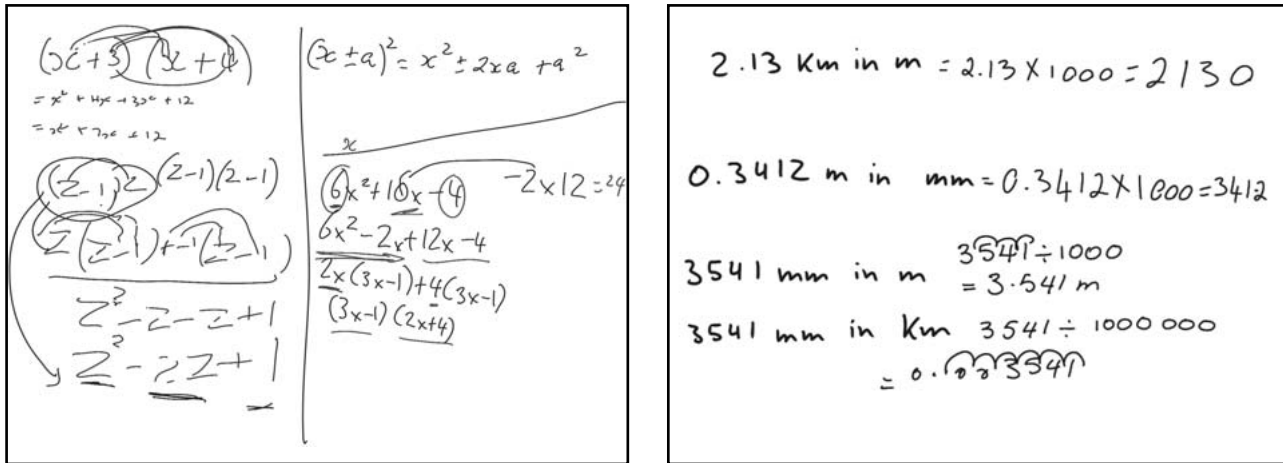


Figure 5. Example of students using a Tablet PC in a tutorial: Foundation Mathematics (a), and Numeracy for Nursing (b).

are that writing is usually easier to read; the screen is being projected; and the student does not have to physically go to the front of the class. The latter also has the effect of changing the power structure of the classroom by giving the control of the pen to the student and the focus is on the screen rather than on the student. While this method was not formally evaluated, students in the class were willing to try it and were keen to use it in subsequent classes. At the beginning it did take a short time for students to get used to the actual writing on the screen.

In a numeracy course for nursing students, while some of the international students were initially uncomfortable writing on the Tablet PC, this approach proved to be very useful as it allowed these students to participate with minimal speaking. It also provided valuable information to the teacher, as it was possible to identify gaps in knowledge and understanding in individual students which in other cases may have remained undetected.

Student feedback

From the student responses to the evaluation of the online sessions in five of the subjects, it was concluded that students valued the interaction, the real-time responses, gained confidence in seeking assistance from their tutor and it broke down the feeling of isolation and was “much easier than the other discussion” (FM distance student). It also improved motivation and kept them on track. The presence of the teacher meant that “conversation tends to stay on topic and less time is wasted” (Foundation Mathematics student), or as another student put it, “on our own sometimes it was like the blind leading the blind” (Data Analysis student). The handwriting was “most helpful in problems that involved diagrams and angles” (FM student). While they said they would prefer a “pen mouse”, they also stated that handwriting was readable and it would have been difficult to experience the tutorials without handwriting. Experience gained from these Messenger tutorials led to the conclusion that for an effective class the size of a group should be about three to six students, with no more than 10 students involved (Loch & McDonald,

2007). Students' comments included:

I have found this tonight to be of great help especially with your handwriting, I feel like I am in a classroom looking up at a chalkboard (FM distance student)

It was my first time using this program, and I found it fairly easy to operate, I definitely give it the thumbs up! It would also make studying chemistry a lot easier, with all the formulas and such. Wish I had it years ago! (FM distance student)

For the Elluminate trial, a mathematics student commented:

This was the perfect way to communicate with others while studying externally, Elluminate allowed the ability to be understood and to demonstrate complicated working out simply and effectively (Algebra and Calculus student, (Reushle & Loch, 2008)).

Table 2 summarises the advantages and disadvantages of using a Tablet PC when teaching one-to-few.

Table 2. Advantages and disadvantages of using the Tablet PC in online and face-to-face tutorials.

Advantages	Disadvantages
<ul style="list-style-type: none"> • It is easy to capture what different groups are doing without being intimidating • It can capture error and reason for error • The novelty aspect is attractive for some students • Online chat sessions are enhanced • Elluminate allows sessions to be recorded for later viewing 	<ul style="list-style-type: none"> • In face to face sessions a clear plan to incorporate its use is essential • For online synchronous sessions it is often difficult to find a mutually agreeable time to meet • Some students take time to adjust to the new technology • Handwriting may be difficult with a mouse only, but not impossible

Using the Tablet PCs in these group based more intimate environments, personalizes the learning and provides timely feedback both for the face-to-face and distance students; again features of teaching excellence.

Consultations: Teaching one-to-one

Students often require more than lectures and tutorials. In this instance one-to-one consultation is another way to teach. This can occur both on line and face-to-face. Teaching one-to-one using Tablet technology maximises the opportunity of this intensive support. Not only is there instant feedback, but the recording can be used by the student at a later time for further under-

standing and reflection. This is a valuable tool in mathematics where students may understand the concept when it is scaffolded with the teacher there. Once the student goes to redo examples or do new ones on their own, they realise gaps in understanding. The student can relive the moment and hopefully recapture that understanding.

How the Tablet PC is used in teaching one-to-one

In 2007 distance education students were provided with mathematics consultation using a Tablet PC and Messenger. Thirteen students responded to a survey about the usability and the usefulness of the electronic handwriting in online consultations. All students surveyed found this more effective than the traditional phone and e-mail consultation for mathematics learning.

This method was also used for face-to-face sessions where a typical mathematical explanation of a solution was captured on the Tablet PC rather than on paper. Audio was recorded using screen and voice capture software. Once the session was recorded into a suitable format it could be given to the student immediately or emailed. The student could then listen to the recording at any time. In the example in Figure 6, a nursing student was learning how to rearrange equations.

This example is often found in the context of drug calculations in nursing. A whole recorded session with the student took about 30 minutes and was 20 MB. As this would have been too large to send, a short excerpt of the session of about six minutes (5 MB) was edited out and sent to the student via email.

At times a captured lecture is not an appropriate way to convey information. Often students do not need to listen to a whole lecture, and while a lecture can be divided into parts, it may be useful to simply record a session focusing on concepts where students get “stuck”. The advantages are that these recordings are normally quite short, can be quick to capture and sent to students and can be used in a variety of circumstances. These learning objects can also form part of a bank of resources available for future use. Figure 7 shows an example within the Camtasia Studio editing process.

Figure 6. Screenshot of a recording from a one-to-one session with a nursing student.



Figure 7. Screenshot of tutor explaining error in student exam, contained within the Camtasia Studio editing suite.

In this example a student asked for feedback on a question that was answered incorrectly in the exam. The exam question was scanned to the teacher's computer and then written on using the Snipping Tool, available for download as part of the free Microsoft Tablet PC Experience Pack. The recording, 1.9 MB in size, was six minutes long and was emailed straight to the student.

Nursing students often have difficulty with converting decimal hours to hours and minutes. In the example shown in Figure 8 the question of converting 0.4 of an hour was explained, first by visually looking at the position of 0.4 of an hour in an imagined 10 hour clock and then converting that to a 12 hour clock. It was then explained by looking at the language of 0.4 of an hour and finally by asking the student to calculate what 1.7 hours would be. This "quick tip" was then embedded into online course material.

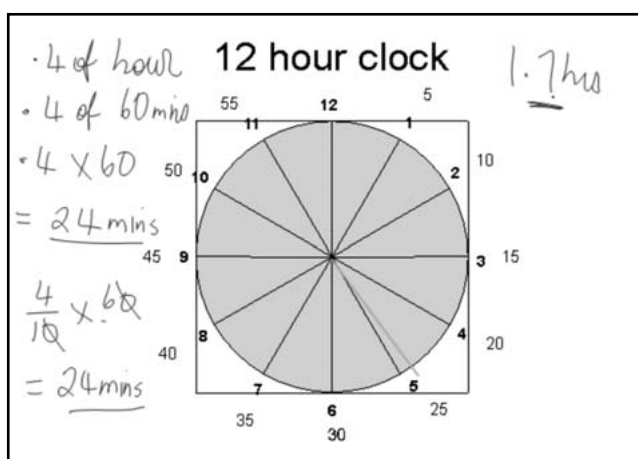


Figure 8. Example of pre-recorded explanation of converting hours to minutes.

Student feedback

Student comments on this type of teaching include:

More tutors in more courses taking part. Now that I've used this method of communication for my studies, I don't want to go back to the old method — e-mail or phone (Foundation Mathematics distance student).

The lecture highlights, the video snippets for worked examples and SPSS [a statistics software program], without these I would have really struggled. (Data Analysis distance student when commenting on the most helpful/effective aspects of the course)

The ability to interact directly, in real-time with a tutor/lecturer, in order to seek assistance on specific questions, and do so in a manner that allowed uninterrupted concentration on the task at hand. This resulted, for me, a much better outcome in terms of learning and retention of knowledge than compared to the ad hoc nature of e-mail (FM distance student)

A survey of the advantages and disadvantages of using a Tablet PC when teaching in one-to-one situations is shown in Table 3.

Table 3. Advantages and disadvantages of using the Tablet PC in a one-to-one situation

Advantages	Disadvantages
<ul style="list-style-type: none"> • The learning moment can be captured for later use and reflection by the student • Recording of the session can be reused for other students 	<ul style="list-style-type: none"> • Recording at a desk with students present can be awkward • Some students are hesitant about participating • Issue of confidentiality has to be considered

Overall staff feedback

The ten staff who have used Tablet PCs since 2007 have commented positively on the pedagogical advantages offered by these technologies. All asked for their own Tablet PCs after trialling the Tablet PC for a semester in their classes. One commented that she observed a marked change (positive) in her student evaluations and that she has become more visual in the way that she teaches and that the tablet has slowed the pace of her lecture down (Biological Sciences lecturer, Tablet Fellowship survey).

Staff using Tablet PCs for mathematics teaching said that Tablet PCs:

- “saved precious time in class”
- “once set up were much less cumbersome than using a whiteboard or overhead”
- “Already I wonder how I ever managed without it. Being able to show graphically what the data looked like was invaluable.” (Loch & Reushle, 2008)

However, there were also comments such as

- “I would like to use the whole whiteboard, how can I do that with a Tablet?”
- “I had some trouble getting it to work.”

The number of Tablet PC users at USQ in all faculties increased considerably in 2009 as funding was made available to purchase additional machines as part of a USQ Learning and Teaching Fellowship. Feedback from this research project is currently being analysed.

Conclusion

This paper is a demonstration of the potential of the Tablet PC and associated technologies for teaching mathematics in university or school settings. It provides a number of ideas on how Tablet PCs can be used in teaching mathematical sciences face-to-face and online at a distance. These ideas are by no

means exhaustive and are presented now to encourage new directions and approaches as Tablet PCs become more affordable. Tablet PCs can create an environment that can maximise student learning opportunities, empowering both student and teacher. If used to its full potential it captures clear and recordable mathematical thinking in action and can provide purposeful and timely feedback. As university lecturers and other teachers move into flexible teaching and learning environments, the Tablet PC is an essential tool.

Teachers at all levels of education are exploring ways to use technology to engage their students. In some instances it can be a simple adjustment however, in many cases it will necessitate professional development in pedagogical use of these new technologies. The benefits for distance or remote students are obvious, but all students can benefit, when they can review, in their own time, difficult concepts. The challenge will be to create these learning objects that will engage and assist in learning.

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