Jl. of Computers in Mathematics and Science Teaching (2012) **31**(4), 363-385

Tablet Technology to Facilitate Improved Interaction and Communication with Students Studying Mathematics at a Distance

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Teaching and learning of mathematics is challenging when lecturer and students are separated geographically. While student engagement and interaction with the course, with other students and with the lecturer is vital to mathematics learning, it is difficult to facilitate this electronically, because of the nature of mathematics. With tablet technology now becoming ubiquitous and many new and inexpensive models entering the market, it is timely to investigate how the distance student experience in mathematics can be impacted by the use of tablet technologies. This paper reports on a case study of a first year mathematics course at a regional Australian university, where distance students were provided with affordable tablet PCs. An investigation of the impact of this technology on engagement and interaction is at the centre of this study. Evidence from journals, students' assessment submissions, screen snippets, student communication and formal student evaluations is analysed. It was found that distance students acknowledged the value of tablets for communicating mathematics, particularly for assignment submission and feedback, but they also recognized the potential for easier interaction with content and the lecturer. This paper highlights the specific benefits and challenges tablet PCs present to the learning experiences in mathematics within the distance context.

Introduction

The importance of engaging first year university students in mathematics has been discussed extensively (J. A. Taylor, 2006). Facilitation of this engagement becomes more challenging in distance education (J. A. Taylor & Mohr, 2001). While there have been many studies on the use of educational technologies to assist in the electronic communication of mathematics (such as tablet technology, from the lecturer's perspective Loch & Donovan, 2006) and to engage distance students (Chen, Lambert, & Guidry, 2010), providing a learner-centred approach in distance mathematics education still has many obstacles. One of these is the lack of natural bi-directional communication of mathematical symbols and expressions between learners and instructors.

The University of Southern Queensland (USQ) is a multi-campus regional tertiary education provider offering both face-to-face and distance modes. A recent study (Loch, Galligan, Hobohm & McDonald, 2011) concluded that it is possible to use inexpensive netbook tablet technology (ASUS EeePC T91®) to engage students in active and collaborative learning in mathematics and statistics when enrolled in face–to-face mode.

This paper reports on the next phase of this study and focuses on student use of tablet technology in mathematics, specifically in distance learning. In the semester following the first phase, the netbook tablet PCs were re-allocated to a new cohort of students enrolled in distance mode in a first year mathematics service course. The tablets were mailed to students across Australia, who volunteered for this study. The aims of this study were to investigate how tablet capabilities (such as inking and touch) may enable bi-directional communication, in the distance mode and how this enhanced communication impacts on student engagement and interaction.

The paper reviews current literature on distance learning, learner-centred education and the impact of tablet PCs. An outline of the methodology is followed by a detailed description and evaluation of the case study. The paper concludes with a summary of future directions to be taken in this research area.

Literature

Literature on using tablet technology as a tool for mathematics communication in distance education is scarce. Therefore, this paper commences with a literature review on the issues faced in distance learning in general, and in mathematics education in particular. Learner-centred education is then discussed with an emphasis on distance learning and mathematics. Finally, a review of tablet technology focuses on the learner-centred approach.

Distance Learning

Engagement and interactivity in face-to-face learning has many similarities with distance learning, however, a shift in approach is essential as "familiar frameworks and markers of everyday life and learning no longer exist, or at least exist in unfamiliar forms" (O'Regan, 2003, p. 81). The distance learning environment also has a particular "social, interaction context, which is very different from that of the traditional, physical classroom" (Bouhnik & Marcus, 2006, p. 300). Distance learning has evolved over the years from a purely correspondence model to an "intelligent flexible learning model" characterised by online elements which include interactive multimedia, internet-based access to web resources, computer-mediated communication, and learning management systems (J. Taylor, 2001). Yet, Sutherland & Saltmarsh (2010) suggest that there has been insufficient attention paid to learning and teaching implications around online learning issues, such as reflective practice, professional learning, socialization and communication (Whitehouse & Wragg, 2006). In this paper, the term online learning will be used when it is specifically referred to in the literature, or where online learning elements are used in the study.

With the correspondence model of distance learning it was assumed that the student "learns independent of contact with the teacher or with other students" (Barker, Frisbie, & Partrick, 1993, p. 39). Such students in general experienced isolation and disconnectedness (Juan, Huertas, Steegmann, Corcoles, & Serra, 2008). Even with the flexible learning model there are a range of emotions experienced, such as bewilderment and confusion, frustration and anxiety, as well as enthusiasm, excitement and pride (O'Regan, 2003). Shame and embarrassment, particularly for women, are other emotions experienced nowadays as technology has allowed the distance learning student to become exposed online. Added to these emotions is inexperience with technology used in the online mode by both students and staff (Simonson, Smaldino, Albright, & Zvacek, 2003). However, online students can also have much closer contact with others in some contexts (e.g. Strambi & Bouvet, 2003), which allows for a learner-centred approach utilising students' and teachers' cognitive, social and metacognitive presence.

In mathematics, online learning can have both significant benefits and challenges. Juan, Steegmann, Huertas, Martinez & Simosa (2010) acknowledge the potential benefits such as freedom from class time constraints, self-pacing and development of technical skills. Challenges may include lower success rates, the type of learner or the design of the online course. Juan, Huertas, Steegmann, Corcoles and Serra (2008) highlight the learner and course design issues with students studying mathematics online. They suggest students' mathematical background, their lack of motivation, overload of courses, lack of face-to-face interaction, and poor integration of mathematical notation into materials including assessment, make it difficult for students to study mathematics online. In addition, unrealistic expectations and time management issues (J. A. Taylor & Mander, 2003) coupled with general anxiety about mathematics, add to the problem of studying mathematics online. Furthermore, online learning requires instructors and students to be trained and proficient in e-learning (Juan, et al., 2008). Teachers also need to gain an understanding of the new pedagogical approaches and empathise with the communication difficulties experienced by students (Aminifar, 2007).

The diversity in mathematics backgrounds can be addressed by using self-paced skill-based materials, authentic problem-solving activities and generic study skills for students with uneven preparation (J. A. Taylor & Mander, 2003). Mathematics anxiety can be managed using a student-centred and in-context approach, using reflective practice techniques developed with maths anxious students in mind (J. A. Taylor & Mohr, 2001). Many of the online learning issues may be alleviated by using a learner-centred approach (Loch, Galligan, Hobohm, & McDonald, 2011; Walczyk & Ramsey, 2003 for a summary of learner-centered approaches in mathematics), which has the potential to ensure distance students experience quality education. In particular, teacher to student interactions should include immediate feedback for activities and results, revisions and models of correct solutions, and the facilitation of communication among students.

Learner-Centred Education

The importance of learner-centred education, particularly in a mathematical context, has been researched before (Loch, et al., 2011). Learner-centeredness, in general, requires teaching approaches that engage students, for example by promoting active learning and providing students with prompt feedback on performance and understanding (Chickering & Gamson, 1987). Similarly, (Tinto, 2009) listed expectations, feedback, support and involvement as four conditions that are supportive of student learning and retention. There is strong evidence that active learning techniques, such as group work and collaboration, enhance student learning when engaging face-to-face (Pascarella & Terenzini, 2005), but transferring these techniques to the online mode is difficult. It is particularly problematic in online mathematics courses. Other approaches to facilitate learning mathematics online for distance students are needed.

Interaction is a key element in pedagogy and is particularly important in e-learning (Bouhnik & Marcus, 2006). Interaction includes interactivity with the content, instructor, students and the e-learning system (Bouhnik & Marcus, 2006). This is difficult to achieve in standard face-to-face mathematics tutorials and even more challenging in the distance mode. Often the most able students are the ones that ask and answer questions on discussion boards, leaving others frustrated or intimidated. Many students are easily overlooked while they may in fact struggle and require support. In addition, students' anxiety and under-preparedness make them reluctant to expose their thinking in mathematics. A safe environment needs be developed to foster interaction, and where misconceptions and errors are the focus for learning, creating an opportunity for everyone to learn. Goos (2002) suggests that students studying mathematics need to recognize their own metacognitive failure. Also, the distance learning environment needs to include scaffolding which promotes metacognition and minimises metacognitive failure.

To enable effective online interaction between the lecturer and students, two requirements are essential. Firstly, relevant technical infrastructure is imperative. Secondly, students need to be willing and able to expose their incomplete level of cognitive and metacognitive understanding. This paper will argue that these requirements are key differentiators between online education in mathematics and non-symbol based disciplines.

The first differentiator relates to the visual nature of mathematical communication. This requires symbols and diagrams to express the content, which is not easily achievable by technology when facilitating online learning. Communicating via diagrams and formulae needs to be a straightforward task (Loch & McDonald, 2007) and requires a platform that enables such communication. Juan et al. (2010) suggest the majority of instructors do not use technology and/or do not have the skills to use the technology effectively. The challenge is to balance student and staff technology skills against frustration thresholds. Although technology has moved on and there are now many other options for communicating mathematics online, including user friendly equation editors and web conferencing for synchronous learning, the issues remaining are still the same. Entering of mathematical notation into the computer, both by students and by lecturers, needs to be simple, fast and natural. Tablet technology allows natural handwriting in digital form, which is why this technology was chosen for this study to facilitate learner-centred interaction.

The second differentiator required is the nature of the bi-directional communication. For example, Smith and Ferguson (2005) commented that "the current e-learning model which is asynchronous and relies heavily on threaded discussions does not work well for math" (para 6). Loch and McDonald (2007) suggested that teaching distance students can be a frustrating experience due to the difficulties of two-way discussions, particularly with problem solving. An atmosphere for student-centred active learning and interaction is needed. This environment should facilitate simple to use bi-directional feedback sequences between lecturers and students using easy-to-create mathematical notation, and a mechanism to capture student cognition and metacognition.

Tablet Technology

It has been shown that tablet PCs support learner-centred education (Cromack, 2008; Loch & Donovan, 2006; Reins, 2007), therefore leading to student engagement, provided there is ongoing professional development for teachers (Neal & Davidson, 2008). A common theme from the literature is that student interaction and prompt feedback on submitted work have been the strong points of tablet technology in mathematics (Loch, et al., 2011).

Previous research has concentrated on the on-campus experience (Fister & McCarthy, 2008) where the tablet PCs facilitated active learning in mathematical sciences has shown positive results. Tablet PCs have also been used in the Distributed Learning model (Blyth, 2010), where students are taught synchronously in classrooms whilst in an environment physically separate from the instructor. At USQ, research into educational technologies for the teaching of mathematical sciences has focused on tablet technology in synchronous online tutorials (Loch & McDonald, 2007; Reushle & Loch, 2008). Additional research investigated deeper learning through lecture screencasts (Galligan, Loch, McDonald, & Taylor, 2010; Loch, 2011) or using screencasts to answer students' enquiries (Galligan, et al., 2010). These studies, however, have concentrated on the one-directional learning in mathematics, i.e. only lecturers using the tablet technology. There appears to be no research on lecturers and students using tablet technology for bi-directional communication for distance students.

This paper explores new pedagogical directions in the teaching of mathematics online using tablet technology, where students and the lecturer have access to the technology, and where learning occurs in geographical separation. At this stage in our research, we are not analysing improved depth and quality of student learning, rather the enhancement of interaction and engagement, which may lead to such improvements.

Background to this Study

Like many university mathematics departments in Australia, USQ provides mathematics service courses to students enrolled in programs across faculties. The courses are offered in dual mode, that is, to students on-campus and at a distance. Increasingly these modes are blurring as all students are able to access material and interact online.

Students in these mathematics service courses are now interacting both synchronously and asynchronously using a Learning Management System which usually provides recorded lectures and discussion boards. In addition, difficult concepts are often explained using short screencasts and just-in-time feedback is given via short screencast recordings. While bi-directionality occurs in the discussion forums, it is difficult to write mathematical notation in these forums

USQ has moved from a correspondence model, where distance students were mailed print-based study books and related material, to a more flexible multi-modal model. Elements of a correspondence model, however, are still present in teaching mathematics. Despite the university's adoption of a flexibility agenda to submit, mark and return assignments electronically across disciplines, all mathematics courses allow students to submit handwritten assignments via post. For students this can mean considerable time delays in obtaining feedback. Some students studying mathematics online submit assignments electronically via an automated assignment submission system. However, most electronic assignments are scanned copies of handwritten work of varying quality. A small number of students use software such as Equation Editor in Word. First year students rarely manage more complex programs such as LATEX to format solutions to mathematics questions. This is where mathematical writing on a tablet PC can play an important role.

This paper details research from a case study where 20 online students were each given a netbook tablet PC for one semester for their first year mathematics service course. The netbook tablet PCs were configured with programs such as OneNote™ , Maths Input Panel™ (MIP), Word™, and Journal™ (all Microsoft); PDF Annotator™ (Grahl), and Jing™ (TechSmith), to enable students to write and communicate. The students had different levels of computer literacy which was addressed with extensive technical support that included guides, email and phone assistance, and online forum support. This paper highlights some of the specific benefits and challenges the netbook tablet PCs presented to the distance students' learning experiences in mathematics.

Methodology

To investigate the impact of tablet technology on distance student learning, a case study approach was taken using both a descriptive and exploratory focus. A case study is appropriate here. As the focus was on the process, context and discovery (Baxter & Jack, 2008), students were asked to complete four journals throughout the semester and were encouraged to submit assignments electronically. From our previous experience with on-campus students' netbook tablet PC use, the journals were structured with specific questions based on the themes that emerged from the previous study. Journal 1 probed student expectations, initial feelings and tablet capabilities; the next two journals focussed on electronic submission and support; and the final journal on meeting expectations and changes in their approach to the tablet technology. Samples of students' assessment submissions, screen snippets, student emails, forum discussions and anonymous formal student evaluations were also collected.

In total, 49 journals were submitted by 20 students. All data were coded to extract themes. We had previously coded a similar set of data for on-campus students and used the same approach (Loch, et al., 2011).

Case Study

The participants involved in this study were all externally enrolled in a first year service mathematics course, which is roughly equivalent to a higher level mathematics subject as studied in the last two years of high school, studying topics up to basic differentiation. Volunteers were sought via email upon course enrolment.

Twenty five students received a netbook tablet PC by post for the semester and were encouraged to use it as much as possible both for studies and in daily life. Five students withdrew from the course within the first few weeks, thus results of this study are based on the remaining 20 students (9 male and 11 female). Nine of these students were enrolled in an Education degree (postgraduate or undergraduate) and five in a Bachelor of Science. The remaining six students were enrolled in a variety of programs. Early into the course, a further four students withdrew, and one student did not submit any assignments. However, data collected from all 20 students have been included in the study.

Results

The main reason for participating in the study was to use the netbook tablet PCs to enhance interactivity and to write and submit assignments electronically, and to interact online. Based on this premise, the study evaluated data with a focus on enhanced interactivity, and prompt feedback on electronic assignment submission.

Interaction

In this section interaction with the technology and the learning management system (LMS), content, the lecturer, and other students will be discussed. This interaction is both cognitive and metacognitive and reveals matters of affect.

Interaction with Technology and the LMS

From previous experience, we knew students would be reluctant to interact with the technology when too much information was presented to them at once. This research thus took on a staged approach, introducing students sequentially to new aspects of the tablet technology.

From Journal 1, most (14/17) students familiarised themselves with tablet specific functionalities such as inking in PDF Annotator, Word or Journal, MIP and Jing and were able to interact with the LMS. At this early stage, when asked to produce a recording (as a means to communicate their maths issues to the instructor) with Jing, only three students managed to submit their recordings due to problems with the small screen size and netbook processing capabilities. Initial feedback from students also indicated that the small stylus made it difficult to write. A larger stylus was sourced and greatly improved the students' writing experience. The following comments from Student G typify the initial frustration levels, approaches and subsequent adaptation when persisting with the interaction of the technology: Initially – *"This is the screencast of me doing one of the examples in the study book. Oh My Goodness!!!!!! It was a frustrating exercise which took me three days, but I finally have worked out how to use Jing and it will be much simpler next time"*. (August)
Later - "*Jing and I do not get along very well. I don't think it helps that I am 'microphone shy'… I sound really ditzy, but the maths is there…. I love the new stylus. I am terrified of losing it, but it does make writing on the tablet much more comfortable and accurate.*" – (September).

Interaction with the Lecturer and Students

Interaction with the lecturer and other students via the LMS was a minor theme that emerged from the analysis of the student journals. For example, one student saw the tablet as a communication tool for online learning and said: "*The thing that I found most irritating* [in previous online courses in maths] *is that when I was trying to explain something, the maths that you end up writing on the screen had to be decoded first before it could be understood. I thought having access to something that would allow maths to look like maths would make this much simpler.*" (Student F)

For students to interact with the lecturer, they were provided with a number of maths recordings to exemplify how they could use Jing to quickly communicate both cognitive and metacognitive issues. While three students managed to submit recordings on request at this early stage, only one student used this technology unsolicitedly as an asynchronous method to communicate with the lecturer. For Journal 2, another attempt to encourage students to create maths recordings was made and six students managed to do this by the end of the semester. Students were still experiencing difficulties with the size of the monitor, slow processing speed and inking (issues to be discussed later). Interestingly, the recordings showed little insight into metacognition or emotion. For example, Student J (Figure 1) simply recorded how to multiply two matrices without articulating the thinking process. The recording merely showed how students solve problems routinely.

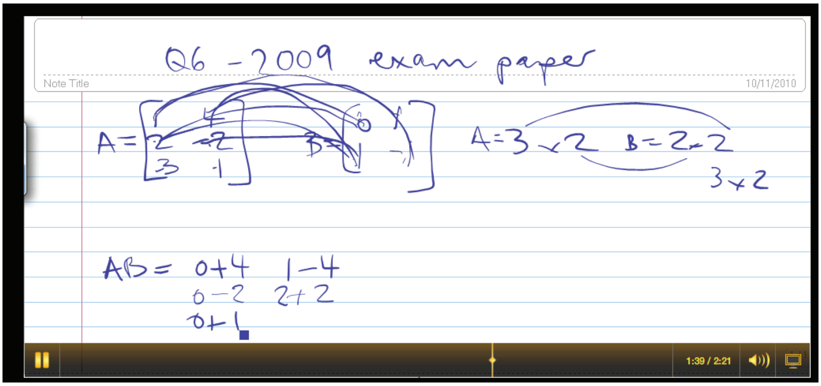

Figure 1. Student (J) using Journal with inking and recording with Jing.

Other recordings provided further insights. For example, student H (Figure 2) simplified this power expression using decimals and was quite methodical in ensuring the use of the correct sign in the index (the final answer was $2.5a^{3.5}b$).

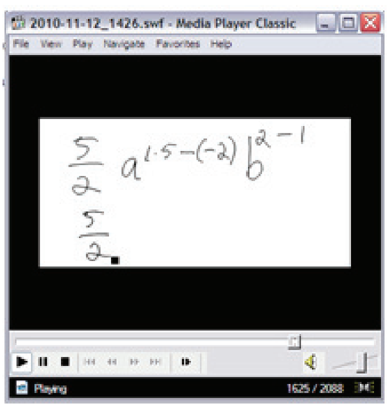

Figure 2. Example of Student (H) submitting a "Jing" recording.

Another aspect to emerge from student-teacher interaction, was about the emotions students experienced when recording themselves. In one example, Student K highlights one of the advantages of live recordings: *Future technology in the coming years is pretty exciting. I think the audio mixed with the visual gives a humanness to the question / explanation... the tone of the voice, and even the mumblings convey so much to the recipient......!* (Student K)

In a second example of student-lecturer interaction, Student F indicated the potential of the technology for learning: "*I can see that it would be a great advantage if I were struggling with the subject and needed to show a lecturer or tutor what I was doing so that I could get some help*."

While there were clear issues with the slow processing speed, students could see the potential for using the netbook Tablet PC for interaction with the teacher. Student F "*I will love being able to show someone how I am doing something and have someone explain to me properly what I am doing incorrectly*". This is the essence of one of the aims of this research.

Interaction with the Content

Interaction with the content was evident in some students' journal entries and emails. Student M stated: *OneNote is the ultimate tool for scribbling notes while studying… when I am revising and I jot down important points. At the end of my study session, I simply print the page and I have all my notes*. Similarly, student B said "*I usually watch the lectures on my work laptop and take notes during the lectures on my tablet*". Student M found it "*exceptionally helpful in my maths course when I need to do some thinking about a question but don't want to type it all up in case I'm on the wrong path*".

Insight into students' understanding of the content can be seen from Student K's Jing recording in an email attachment (Figure 3) asking how to solve a log equation.

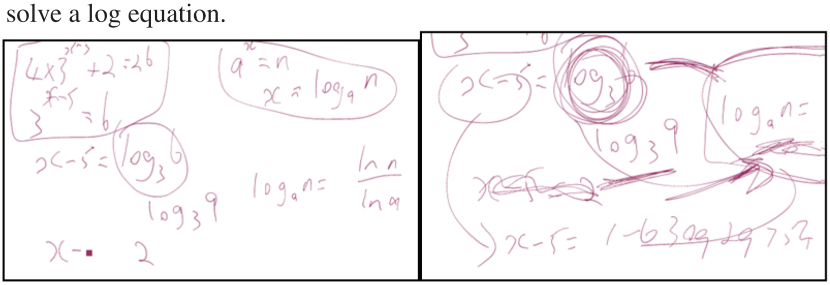

Figure 3. Student K's submitted recording using Jing and inking (two snapshots in time).

In this example, the student had $x - 5 = \log_3 6$ and thought there should be a simple solution as he said if it was $\log_3 9$ the answer would be 2. He said he did get the answer using the change of base rule (circled in Figure 3 on the right) but was intrigued that is was a decimal and not an integer answer. This example shows the student thinking around the problem which gives the lecturer invaluable insight into student approaches.

In summary, evidence was found for interaction with the learning system, the instructor, the students and content. Some cognitive, metacognitive and emotive issues emerged, but the full potential was not realised. It may be that students' reluctance to expose their thinking as well as technology issues, restricted the interaction with the lecturer in particular. There was however, a deliberate emphasis on interaction through the assignment submission.

Assignment Submission

For the distance learner, prompt feedback is an essential element in interaction. This includes feedback on assignment tasks and on student queries through student-to-teacher interaction. Based on this premise, students in this study were encouraged to submit their assignments electronically.

Assignment submission had three variations: electronic submission of assignments compiled with tablet technology (MIP, inking or combinations of MIP and inking); electronic submission of scanned assignments; and posted handwritten assignments. For the first assignment, half of the students in this study submitted their assignments either by posting handwritten assignments or by submitting electronic scanned copies. The remaining students submitted their assignments electronically having used a combination of inking and MIP. All electronic submissions were marked using a tablet PC and feedback was returned electronically within a week of submission.

The following section provides examples of student work from their assignments, emails or Jing recordings relating to their assignments. Typical inked written work is shown in Figure 4.

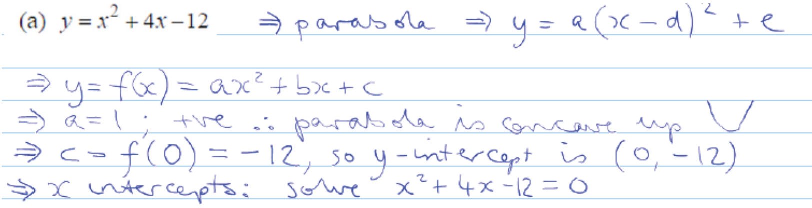

Figure 4. Sample of student writing using the tablet.

Many students prefer the neater appearance of typesetting, which is tedious with typing or even an equation editor. The MIP, while providing conversion from mathematics writing to text, needs time and patience to use it effectively. The examples in Figure 5 exemplify this: the first showing expertise; the second showing incorrect notation in MIP and the third, a student's attempt typing with annotations.

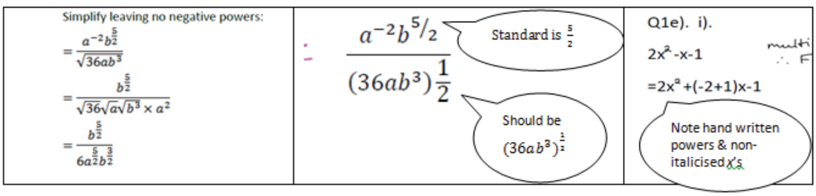

Figure 5. Examples of using typesetting.

Similarly, using word inking in MS Word needed patience as the netbook Tablet PCs were slow. Most students did manage to ink neatly eventually. Student K after assignment 2 commented: "*working in word and using the inking tool seems to be working much better...I am getting much smoother results, and getting more comfortable using it!*"

For assignments, many students typed what they could, and added diagrams and graphs. They then used the inking tool to annotate, for example on a graph or a matrix (Figure 6) to complete the answer.

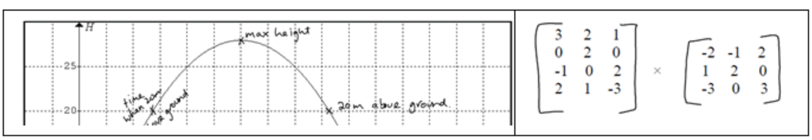

Figure 6. Example of annotating a graph and matrix.

Diagrams in particular were created using the tablet, both in assignments and in some emailed conversations. Figure 7, for example, was an extract from an email to the tutor about an assignment question.

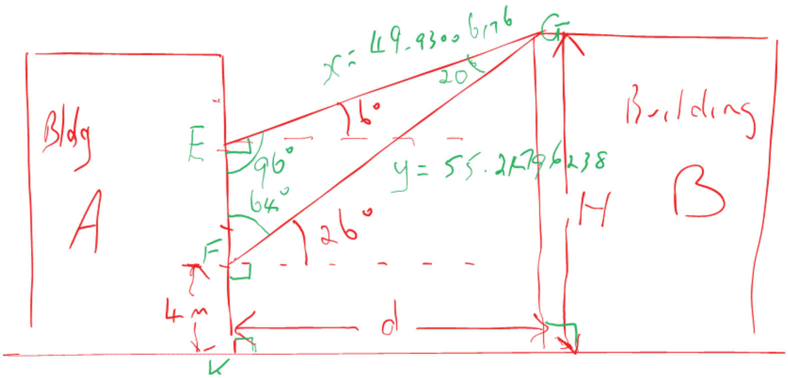

Figure 7. Example of student freehand drawing of an assignment problem.

While there has been a general increase in students submitting assignments electronically (e-assignments) at USQ in recent years, there has been a reluctance to do so in mathematics. Apart from the issue of mathematics communication, students are nervous of e-submissions and are still unfamiliar with the advantages. This is evidenced in anonymous student evaluations: *“I prefer to be able to mail the assignments in. You then know they are on their way, EASE* [the USQ submission system] *is sometimes not so user friendly and some systems don’t work so well with it. Receiving physical feedback on your written answers is also very helpful, especially in a subject where you can go back through the steps/processes to see where the errors were made.”* And another: “*I did* [submit electronically]. *I was nervous every time I hit the submit button, wondering whether my connection would drop out or my computer crash or some other IT problem occur… But they went through without a hitch. It was very easy.”*

In contrast, the comments about timely assignment feedback were very positive. One student (anonymous) commented: “*I was so impressed with the turnaround of on assignments. In previous courses I haven’t received feedback before completing the end of semester exam. This is a HUGE credit to the teaching staff. The students do really, really appreciate it ! :)*”

By the end of the semester, students in the study had become familiar with using the tablet features for submitting e-assignments. Eventually students identified multiple advantages of e-submissions as summarised in Student F's comments below.

Student F: "*I much preferred submitting assignments using EASE. The feedback came back very quickly and was exactly as it would have been had a lecturer written feedback on a paper assignment. It was great…and I can store the assignment with feedback on the computer, without having to store a paper copy*".

Overall, the electronic submission and quick turnover rate was successful. Students could also see the benefits of tablet technology to produce assignments and interact more effectively with the lecturer.

Issues

From our previous research, a number of issues emerged about the size of the netbook and student frustration levels. Students were also concerned with the level of neatness for inking in electronic assignments. Based on these findings, we structured the surveys and journals to include specific questions on these issues which are now briefly discussed.

Size of the Netbook Tablet PC

Within the first few weeks the most frequent positive comment was about the portability and touch screen. Some students liked the handwriting recognition tool, but only one student specifically favoured the freehand writing. Issues emerged early on about becoming familiar with the MIP, the small screen size and the time it took to gain proficiency in the programs with some students taking five hours or more a day to be able use the computer proficiently. In addition students had to become accustomed to new software such as Windows Journal (5 students), Jing (9), MIP (12), and OneNote (7). After an initial spike, students' frustration levels decreased, as they adapted to the technology and lowered their expectations regarding the processing capabilities of the netbook tablet PC. Such realisation is reflected in Student K's comment: *There is a BIG difference between a Jing on the tablet, and on your good machine.....I think the tablet just struggles to have the processing power to run Jing as well as PDF annotator at the same time…(Student K).*

As with the previous research by Loch et al (2011), the netbook tablet PCs' portability was again seen as beneficial, but was overshadowed by reduced screen capabilities, slow processing speed, and the resultant writing difficulties. Most of the students adapted successfully to the technology eventually, with some using it every day and others using it just for the assignment or task at hand.

Student Frustration Levels

At the end of the study, students were asked to rate their frustration levels for the first two weeks and again at the end of semester. Figure 8 shows these frustration levels decreased over time. Student P stated: "*My attitude has changed. I now see it as helpful tool and not a hindrance to my learning of Math.*"

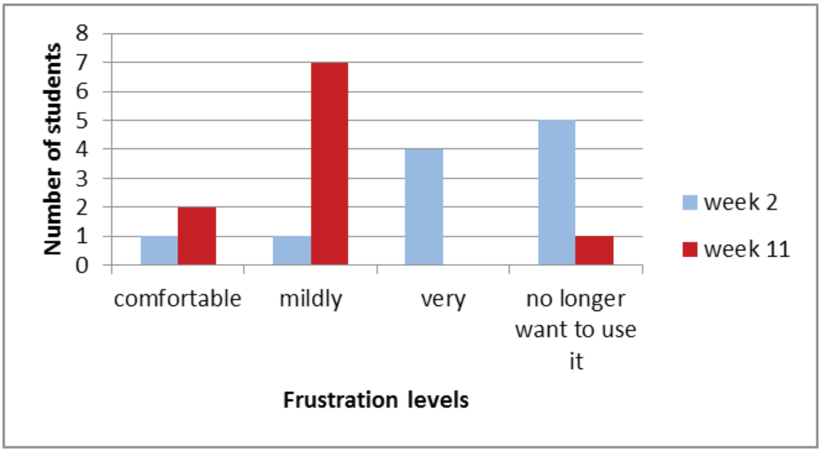

Figure 8. Students' level of frustration at week 2 and 11

While students chose to participate in this study voluntarily, most of these students appeared to be early adopters of technology (and achieved high results for this course), so were willing to persevere despite early frustrations as they saw the potential benefits of the tablet.

Neatness of inking

One recurring theme highlighted students' concern with the professional presentation of their assignments. That is, the majority of students found that their assignments were of unacceptable quality due to their perceived lack in neatness. While we stressed that as long as the inked work was legible to the markers, many students preferred to use the MIP for neater output or preferred to scan their handwritten paper assignment rather than submit something that looked messy. Student P emailed a sample of her work (Figure 9) to gauge acceptability, but decided to scan and send it as a handwritten paper assignment.

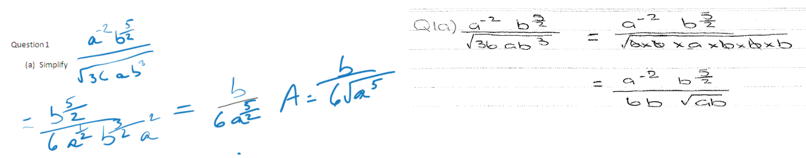

Figure 9. Sample of student P's inking for assignment 1 (left) compared to scanning (right).

Similarly, student (K) emailed: *I'm a bit embarrassed that this is the neatest I could be.......If this isn't acceptable, can I post it in, as I can do much better on graph paper with a pencil*? Following the markers confirmation, Student K submitted the assignment electronically including an inked graph as in Figure 10.

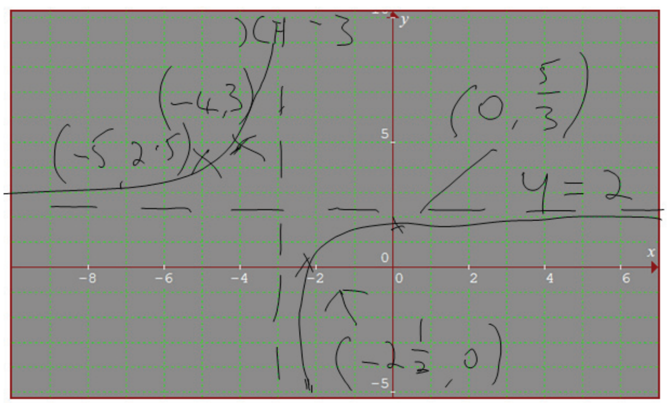

Figure 10. Sample of Student K's work using inking on a graph.

While the size of the tablet was an issue already identified in our previous research with on-campus students, frustration levels were more of an issue in this study with students studying at a distance. However, with our heightened awareness of frustrations, we were able to address the issues, so that by the end of semester students were able to appreciate the benefits of the tablet technology. In an online mode, neatness of writing became an issue for students in this study. This would need to be addressed early, either through improved technology or raising awareness of limitations, if such technology is to be embraced in the future.

Discussion

The ten students who completed the full study had better overall results than those who didn't participate at all (mean 90% compared to mean 54%). Reasons for this may have to do with the type of student who is willing to participate in such studies, more than any particular aspect of the study itself. It was evident that these students were also active participants in the online learning environment by posting comments and viewing much of the material available online.

It could be that these high achieving students also expected of themselves professional high quality assignments, hence the emergence of the issue on neatness. It may also be that because half of these students were enrolled in an education degree (involving mathematics teaching), they could see the pedagogical implications of tablet technology for mathematics learning. A study involving the full range of students within one degree program would have to be undertaken to confirm these speculations.

By comparing this and the previous on-campus study, it became evident that there were differences between external and internal students. The level of engagement was much lower in the distance students, and this combined with the asynchronous nature of the course, led to delayed communication in support and learning. This is probably due to the nature of the online learner including issues of mature aged students with more family and work commitments, and personal issues. In our previous paper we concluded that environmental factors such as tutor, student, learning space, availability of other technologies, and subject content, had an impact on the nature of learning. In a distance environment these factors, while important, adopt a different emphasis. The role of the tutor remains important, but in an online learning environment the attitude and approach of the student becomes critical. This is because online students are responsible for their own learning and choose, whether or not, to become involved in activities and engage with the LMS. Whilst the learning environment is moulded by the student and the tutor, it is also influenced by factors such as time, work and home life which students may find difficult to control.

Conclusion, Recommendations, and Future Work

This paper has demonstrated that affordable netbook tablet PCs can enhance interactivity in the learning of mathematics. While the full potential was not realised, interactions with the technology, the content, and between the lecturer and students, did assist learning. It also enhanced the students' assignment submission and feedback turnaround times. In addition to findings from our previous study relating to processor speed, faster processing is essential to reduce student frustration levels and facilitate neater inking in assignments and communication to the lecturer.

Our on-campus study suggested a university-wide provision of student tablet technology using next generation netbook tablet PCs (or slates). As distance students do not require a portable tablet PC for note-taking in lectures and tutorials, all that is required for the distance student is a peripheral inking device such as a graphics tablet. Our study suggested distance students appreciated the capability for writing assignments and for communication, and had no need for a second computer. Regardless of the technology supplied, both early and ongoing technical support is critical, as is reflected in both studies.

The online mode presents a different set of environmental factors that influences tablet technology-enhanced learning and teaching. In particular, the understanding of the student and their learning environment (physical, social and emotional) is critical to success. An extension to this study just completed, explores distance students' use of inexpensive graphics tablets, and has negated the frustrations identified with the netbook tablet PC. Future research can now focus on improved inking technologies to facilitate effective learner-centred education in mathematics for distance students which may facilitate enhanced conceptual development.

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