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Learner-centred mathematics and statistics education using netbook tablet PCs

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Tablet technology has been shown to support learner-centred mathematics education when this technology is available to both the lecturer and the students. However, cost is often the barrier to students’ use of tablet PCs for their university studies. This paper argues that more affordable netbook PCs with tablet capabilities can be viable alternatives to full sized tablet PCs to enhance active and collaborative learning in mathematics and statistics.

For a whole teaching semester, netbook tablet PCs were given to volunteer students from two different cohorts. Students were enrolled in nursing mathematics or introductory statistics in non-mathematics majors at an Australian university. The aims were to gauge the suitability of this technology and to identify what active and collaborative learning emerged in these first year classes. While the netbook tablet PCs were actively promoted in their tutorials, of additional interest was students’ use of the technology for any aspect of their studies both inside and outside the classroom. The outcomes of this study were to inform a university decision to provide inexpensive tablet technology to larger cohorts of students.

The results highlight different approaches required in the mathematics and statistics classes to achieve collaborative and active learning facilitated through the technology. Environmental variables such as the tutor, student, learning space, availability of other technologies and subject content impacted on the nature of learning. While learner-centred education can be facilitated by inexpensive netbook tablet PCs, we caution that the savings may come at the expense of computing power.

Keywords: tablet PC, netbook tablets, mathematics, statistics, learner-centred, student engagement, active learning, collaboration

Subject classification codes: 97U50, 97U80

1. Introduction
A challenge for any tutor is to engage first year university students undertaking mathematical studies. Making the mathematics relevant to students’ studies and their future careers can be one step towards overcoming this challenge. Another is to actively engage students in learning mathematical concepts by fostering a learner-centred approach. It has been demonstrated in the literature that learner-centred education can be facilitated through the use of tablet PCs by students, when the technology is integrated by the tutor in face-to-face teaching activities.

Despite considerable discounts since the arrival of the iPad®, full sized tablet PCs are still fairly expensive and widespread distribution to students is out of reach for many universities. Recently, the first netbook tablet PCs were released to the Australian market and the opportunity arose to revisit the affordability of student tablet PCs. This development led to the study described in this paper.

At the University of Southern Queensland in Australia, funding was made available to trial a classroom set of Asus EeePC T91® netbook tablet PCs. These computers were considered suitable as they cost less than AUS1000 (compared to AUS2500 for a standard tablet PC at the time). Students were given these tablet PCs for a whole semester to investigate how they would use them for learning and for
personal purposes. The outcomes from this project informed University management about considerations to make inexpensive tablet PCs available to all students.

Since most previous experience with tablet technology at the university had been gained in the mathematical sciences, the trial of the netbook tablet PCs was undertaken in an introductory statistics course and a nursing mathematics course. Both were taught by lecturers experienced in the use of tablet technology for electronic writing of mathematics in various teaching situations, both in face-to-face classes and distance education [1, 2]. The focus of this study was on applying tablet technology to engage students in active learning and collaboration.

Outcomes lead to the conclusion that it is indeed possible to use the inexpensive netbook tablet technology to engage students. However, as with many netbooks, the cheaper purchase costs were offset by reduced processing capabilities. In some instances this became a source of frustration and a barrier to effective use. We envisage that experiences highlighted in this paper will guide others who are interested in deploying netbook tablet technology to students undertaking mathematics courses.

The paper reviews current literature on learner-centred education and the impact of student tablet PCs. An outline of the methodology is followed by a detailed description and evaluation of two case studies, one in introductory statistics and the other in nursing mathematics. The paper concludes with a summary of future directions to be taken in this research area.

2. Literature

2.1 Learner-centred education

Mathematics teaching approaches need to take into consideration the diversity of students undertaking some form of mathematical study. Today, levels of mathematical and technical competence and literacy expected of the workforce are higher than they have ever been [3]. In addition, teaching approaches need to become more inclusive to satisfy the higher demand for mathematical skills and expertise [4].

Such a more inclusive approach would centre on the learner rather than the instructor. Learner-centred approaches engage students, for example by promoting active learning which may also include collaborative work. In a review of the literature on active learning, Prince [5] defines the core elements of active learning as “student activity and engagement”, in contrast to the traditional lecture where students are passive recipients of information from the instructor. Active learning is ‘learning by doing’, but it is also an attitude required of both students and teaching staff [6]. Activities need to be carefully structured to develop deep understanding and promote thoughtful engagement on the part of the student. There is strong evidence that active and collaborative learning techniques enhance student learning [7, 8]. The core element of collaborative learning is the emphasis on “student interactions rather than on learning as a solitary activity” [5]. Collaboration leads to better student performance and has been shown to reduce attrition.

While this compelling evidence for the effectiveness of learner-centred approaches has identified the need to focus on the learner, it also suggests moving away from traditional lectures. However, engaging students in mathematical science classes may not be an easy task especially where such courses are mandatory and are perceived as difficult. In addition, students who perceive mathematics as difficult report high levels of anxiety and their performance levels decrease [9]. As a result,
general and context-specific strategies are suggested to promote active learning in mathematics [10].

Since interaction in face-to-face classes is often limited to verbal responses from students, the shy or insecure student remains silent, thus making it difficult to gauge if all students can communicate the solution to a problem. What is needed is a safe environment, which enables participation from all students, where scaffolding assists in minimising metacognitive failure [11]. This is where tablet technology can play an important role in providing a feedback mechanism for tutors and students whilst supporting a platform for learner-centred active learning and collaboration.

2.2 Student tablet PCs
Tablet PCs support active learning and collaborative learning [12], particularly when both students and tutor have access to this technology. The literature on the impact of tablet PC classes on student learning is growing quickly, mainly from the disciplines of engineering and computer science education. Reports of very high student participation rates in voluntary tablet activities [13] are complemented by lecturer feedback of using class time more efficiently since they ‘can focus on […] student misconceptions rather than […] concepts already mastered by the students’ [14]. The use of regular, real-time, formative assessment with immediate feedback aids student metacognition and helps lecturers address misconceptions during ‘teachable moments’ [15]. However, tablet PCs may pose a physical barrier during face-to-face verbal communication [16], and with that a barrier to collaborative learning.

In mathematics teaching, a more active learning environment has been created in calculus and mathematics classes for liberal arts students [17], with students solving problems in groups on tablet PCs with instructor guidance. This approach has led to improved student performance, but does not automatically result in students asking or answering questions of their own accord [18]. A significant change in perceived levels of participation has been found in the mathematical context [17], where students who described themselves as quiet before using tablet PCs had become active participants in class.

Fister and McCarthy [19] required mathematics students to take responsibility and ownership for their learning, as they were to come to class prepared, provide strategies to approach problems, brainstorm in groups, and share solutions wirelessly on electronic whiteboards. Exam scores were significantly higher for students who had taken part in the interactive tablet PC classes, and students ‘felt they had learned the concepts well’. A major outcome from the use of tablet PCs described by Fister and McCarthy [19], which should not be underestimated, is that it led to campus-wide discussion and coordination of effective university teaching.

Interestingly, a radical change in pedagogical approaches may not be necessary to obtain the positive outcomes of active learning with a tablet PC. In engineering mathematics education, Hieb and Ralston [20] focused on the (private) note-taking ability of the tablet PC for students. This resulted in a difference in the lower end of the grade distribution, with more students passing than before. Elsewhere, tablet PCs trialled in three introductory mathematics classes have been shown to facilitate a ‘change in the fundamental activities of students from passive recorders to active participants’ with improved student attendance and retention [21].

Research to date on tablet PCs and their impact on learning suggests they are ideally suited to the mathematical sciences and, with careful planning, can be utilised in a number of ways to promote active learning. This paper builds on these positive experiences and explores more affordable technology, with very different
technological and pedagogical foundations, thereby encouraging active learning among two different student cohorts.

3. Methodology

To investigate the impact of tablet technology on student learning and to evaluate its suitability for the University’s purposes, a case study approach was taken using both a descriptive and exploratory focus. A case study is appropriate here as the benefit ‘is in the process rather than outcomes, in context rather than a specific variable, in discovery rather than confirmation’ [22].

Students were asked to complete an anonymous initial survey, regular journals and a final survey. Student feedback was sought on the usefulness of the netbook tablet PCs in their academic and daily lives. Some student demographic data were also collected. Teaching staff submitted regular reflections on the classes. One author observed both tutorials in action and one class was video recorded. In total, 28 surveys were completed, 64 student journals submitted, 16 staff reflections written, 10 class observations documented, and the video including transcript evaluated.

To ensure internal validity, three sets of student journal data were coded individually by the researchers. From this, common themes and sub-themes were identified. Once these were negotiated, the remaining data were jointly coded and themes quantified. Finally, taking a phenomenological approach, six student journeys were documented to gain an understanding of the diversity of experiences across the semester. Extracts from three of these are described later in this paper.

4. Case studies

Participants in this study were recruited from an introductory statistics course and an enabling nursing mathematics course. Twelve students from each course volunteered to participate and were subsequently placed in separate tutorials for their respective courses. Each student was loaned a netbook tablet PC for a semester with the requirement to use it in the tutorials. They were furthermore encouraged to use it as much as possible both for study and in daily life. Students ranged in age from 18 to 58 with a median age of 28. There was diversity in computer literacy amongst students across groups which was addressed through workshops held at the beginning of semester followed by ‘just-in-time’ support, as required.

The aim was to study the phenomenon of the effective integration of netbook tablet technology in university classrooms. The two classrooms chosen had different learning spaces, technological equipment, teaching style and student attributes, as is described in detail below.

4.1 Case One: First year statistics

The statistics group were taught in a regular tutorial classroom with grouped tables and multiple whiteboards (Figure 1a). Prior to this study the tutor had provided paper-based tutorial exercises containing spaces for answers. Students had been encouraged to collaborate on exercises through discussion and working on the whiteboard closest to their group. In the previous semester, four laptops, one for each table, had been shared by students to analyse tutorial datasets. However, one laptop amongst five students had been problematic as not all could see the screen at once.

In this study the provision of netbook tablet PCs gave each student individual access to statistical analysis software both in and out of class. Students used the
wireless connectivity in class to refer to lecture notes and statistical tables on the course website to support their learning. When students downloaded electronic versions of tutorial documents, the tablet technology enabled them to write directly into the spaces provided. The tutor used electronic writing on the classroom pen-screen monitor to reinforce the use of electronic writing employing tablet technology. On one occasion the tutor used a single tablet PC to explore the collaborative solution to a problem. The tablet PC was passed to individual students to contribute to a solution. As the tablet PC was wirelessly connected to a projector, everyone could see the solution unfold on the projected screen. In this classroom the focus was to gain insight into adaptation to the technology to see what impact it had on classroom interaction both amongst students and between students and course content.

(Figure 1 here)

Figure 1: (a) Statistics tutorial and (b) Nursing tutorial (computing component shown)

4.2 Case Two: First year nursing mathematics
This course covered mathematics and computing content, and in the past both parts had been taught in a computer laboratory. This time the tutorial was held in a laboratory specifically created to trial a variety of educational technologies (Figure 1b). The room hosted five data projectors, with screens at the front and sides. No whiteboards were available, which meant that the tablet writing capabilities were vital for impromptu explanations of mathematical problem solving. The focus in these classes was on how the display of student tablet content to one of the many available screens could facilitate collaboration and active learning. The teaching space allowed flexible seating from where students opted to connect to the projectors. Students shared what they were doing live via the projectors, but had the control to switch away from public view if they chose. Once students started working on mathematics problems, they wrote their solutions on their netbook tablet PC screens. Projections from multiple tablets were then available for lively discussion. This ability to see, discuss correct and incorrect answers and follow different approaches to problem solving, promoted collaboration and active learning.

The tutor had used one tablet PC in previous semesters to facilitate collaboration. However, the single tablet PC setup was driven entirely by the tutor who decided which student would be given the tablet to write on. With individual netbook tablet PCs, the dynamics of the class changed as the tutor became a guide for the students, with discussions instigated directly from student work.

At times the whole class worked on the same problem; at other times students worked in pairs, small groups or individually. The group work usually emerged naturally, and was not necessarily initiated by the tutor. In contrast, in previous semesters each student was restricted to sitting in front of a PC in a standard computer laboratory and collaborated with others only when encouraged by the tutor.

5. Results
The aim of this study was to identify if netbook tablet PCs can generate a student-centred class environment through active learning and collaboration, and how this
particular technology was suitable for student use in general. These aims are now addressed.

5.1 Active learning
Staff reflections and observations were evaluated to identify to what extent active learning had taken place using tablet technology, and in how far this led to a perceived change, compared to previous semesters. Two distinct situations emerged. During the statistics tutorials active learning was identified by students’ interaction with the content that was downloaded wirelessly from the course website. That is, students accessed lecture notes, course resources and statistical analysis software much more readily than they had in previous semesters. In addition, they could write answers directly into the tutorial worksheets on the netbook tablet PCs.

In the nursing mathematics tutorials students had online access to course material as had been the case in previous semesters. Additionally, the technology enhanced learning laboratory allowed the projecting of multiple netbook tablet PC screens which demonstrably promoted student activity. For example, the multiple screen projections could show different written or visual explanations of mathematical concepts and student solutions to problems, simultaneously. This increased active learning and student engagement.

The following are extracts from journals or survey responses from three students, who were very actively involved in the project. Nursing student Tracey (pseudonym) was impressed with the netbook tablet PC. She said she was ‘absolutely amazed at what it does, and [that she was] getting more reluctant to surrender it at the end of the trial ;-)’.

Active learning was identified in her use of the netbook tablet PC in lectures and with readings. She used it to take notes during lectures (annotating with the stylus) and found this ‘much easier than fiddling with pens that would run out of ink’. It had ‘made the world of difference’ as she was now using the netbook tablet PC as an ebook reader with annotation capability.

Statistics student, Louise (pseudonym), was positive about the features of the netbook tablet PC. There were a number of tablet functions that Louise liked, in particular the mathematics input panel which she used extensively. She said ‘I am still so glad of being able to use math input as it is just so easy to write on the screen and transfer it into word as type’. She also used the netbook tablet PC to take notes, but found scrolling through longer documents frustrating due to slow processing speed.

Not all feedback was positive. Many students found the touch sensitive screen annoying at times. Another student, Sue (pseudonym), found it “sometimes easier to just write on a piece of paper rather than struggle with the pen”. Tracey however, was confident she could overcome her difficulties. She reflected “I had problems with my hand touching the screen when I was writing fast…. Not to worry though, practices makes perfect.”

While active learning was evident in both classes, the type of student activity differed in each. From staff reflections, this difference was attributed in part to subject content, learning space and tutor teaching style.

5.2 Collaboration
Collaboration, while encouraged in both classes, was observed to varying degrees. Even though both tutors incorporated activities to facilitate this into their classes, some students did not participate in them collaboratively.

For the statistics class, a lack of collaboration amongst students was observed. Even though these students were encouraged to discuss the tutorial exercises, they
seemed to be preoccupied by the myriad of online resources they could access with their individual netbook tablet PCs. Having all of the content at their fingertips had some advantages, but it also meant that they did not have to prepare as much for the class beforehand, nor be familiar enough with the content to discuss it with other students during class. This suggests that having access to individual netbook tablet PCs may have hampered collaboration in this setting.

In contrast, nursing students were observed to collaborate to a high degree. They showed each other their work both on the projected screens and around the table. Collaboration was present throughout the semester, in contrast to previous years. The video recording of this class showed that students were collaborating by sharing their knowledge of mathematics and how best to work the technology. For example, at least seven students were involved in a lively discussion on units of measure and correct drug calculations. They were able to identify, discuss and correct a mistake shown on two students’ screen projections, and agree on the correct unit. This critical thinking and questioning approach is vital for these students’ future careers as nurses, where numerical mistakes could potentially cause fatalities. The netbook tablet PCs had facilitated a collaborative learning environment. The video evidence showed students comfortably making mistakes without losing confidence. Student collaboration also extended beyond the classroom. For example, students reported they completed assignments in the library with the tablet PCs.

While collaboration was observed in both classes, the level of collaboration was very different. Staff reflections again reinforce the influence of subject content, learning space and tutor teaching style on level and type of collaboration. In addition, the availability of other technologies such as multiple projection screens appeared to influence collaboration.

5.3 Suitability of the Technology

From an analysis of the data, four themes relating to technology emerged: student uses of the technology; hardware (form factor); software relating to handwriting functionality; and engagement (adaptation to the technology).

Nine of the 24 students used their netbook tablet PC frequently with two students saying they used it infrequently. Uses included taking and annotating lecture notes, accessing additional resources during classes, and for exam revision. Students appreciated the convenience to take their studies with them wherever they went - to a nursing clinic, on holidays, to an airport or to their local fast food shop.

Students liked the compactness and light weight of the netbook tablet PC, with one student (new mother) commenting that ‘the fact that the tablet is so small is great as for me I can put it in the nappy bag’. However, keyboard and screen were noted as rather small by most students. While students liked the touchscreen, this netbook tablet PC contained only 1GB of RAM and a slow Atom processor which compromised performance particularly when writing and multi-tasking. The sensitivity of the tablet screen to touch also required a degree of adaptation.

Of particular interest was how students used the handwriting facility. They were excited about the handwriting conversion tool, but found it required practise and they needed to write slowly. A statistics student, who persisted, was able to submit her assignment electronically using the handwriting functionality to sketch graphs. Many found the stylus small and unresponsive. When given a larger stylus, students reported marked improvement in the writing capability. While the math input panel was available to all, only a few enthusiasts used it, as it required a degree of mastery.
While there were some issues with the technology, mostly related to the size of the screen and keyboard, and processing speed, the portability far outweighed these shortcomings. Most of the students adapted successfully to the technology, with some using it every day and others using it just for the particular class or task at hand.

6. Discussion
This research found noticeable differences between the two classes in terms of two key aspects: tutor interaction with the technology and the learning space; and levels of active learning and collaboration observed. These key aspects are discussed in relation to the results presented in the previous section.

Teaching style, previous experience with technology, attitude towards new technologies and learning space, all influenced how the technology was integrated into the two classes. As a result, tutors needed to pre-empt teaching moments and improvise when technology challenges emerged. Classes incorporating tablet technology demanded more preparation and were perceived by tutors as more intense as they felt more tired at the end of a two hour tutorial. Central to the approach taken by each tutor was the subject content and learning space provided. The nursing mathematics class essentially revised mathematics in a new context. While it required more setup time and experienced more system complexity in the technology enhanced learning laboratory, the tutor was able to compensate through a flexible approach to her teaching and the presence of on-the-spot technical support. The wow factor, both of the physical environment and the netbook tablet PCs, certainly had an effect on student interest, but it did not distract from the learning overall. The favourable comparison with the previously used traditional computer laboratory environment was the impetus for the tutor to continue with a similar learning space in the future. On the other hand, an introductory statistics class has unfamiliar content for most students and required the tutor to take a more controlled approach to focus attention on key concepts during classroom discussion, while still allowing students the freedom to incorporate the tablet technology into their learning in their own way.

With the use of the netbook tablet PCs, active learning and collaboration were evidenced by students engaging in tutorial activities. At times the tutor initiated opportunities for deep understanding and thoughtful engagement; at other times the tutor merely facilitated such engagement. This study highlighted that active learning along with varying levels of collaboration were manifested in different ways which appeared to be environment–specific (teacher, student, learning space and subject content). In the nursing mathematics class, the tutor’s innovative use of technology, the multiple screen projections, ‘coolness’ of the futuristic-looking technology-enhanced classroom and the students’ familiarity with course content contributed to a wider variety of active learning opportunities and perceived higher levels of collaboration. In the introductory statistics class, the tutor’s more directed approach in a low-tech classroom, where students were unfamiliar with the content, still provided active learning opportunities, but collaboration was observed at a much lower level. However, this could be partly attributed to the nature of the students. Sharing one netbook tablet PC between two students in this more traditional classroom setting might be more conducive to collaboration.

7. Conclusion, recommendations and future work
This paper has demonstrated that affordable netbook tablet PCs may be alternatives to full sized tablet PCs and can enhance active and collaborative learning in mathematics and statistics. However, faster processor speeds would be beneficial to more efficient and effective use of the technology. In particular, levels of active learning and collaboration facilitated by the technology and suitability of the technology have been investigated. While there was a positive attitude towards the portability of the netbooks, some disadvantages were noted in relation to size and processing capabilities. From this experience, it is recommended that a university-wide provision of student tablet technology should ideally focus on next generation netbook tablet PCs (or slates) with faster processors, whilst retaining portability. This study also uncovered the need for on-the-spot technical support and reliable wireless connectivity to avoid disruptions to collaboration and engagement with technology.

For both active learning and collaboration, environmental factors were important influences on the tablet technology enhanced learning and teaching. These environmental factors appear also in an extension to this study just completed which explores distance students’ use of netbook tablet PCs. Future research will investigate improved tablet technologies along with identification of the most influential factors which contribute to learner-centred education in mathematics and statistics.

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