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Conceptualising, implementing and evaluating the use of digital technologies to enhance mathematical understanding: Reflections on an innovation-development cycle

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Introduction

Mathematics plays an essential role in everyday life and underpins countless 21st century innovations from engineering design, to forecasting earthquakes, the stock market or the weather. Yet an increasing number of students in Australia and internationally are less engaged with mathematics both at school and university (Thomas, Muchatuta, & Wood, 2009). The three key issues of preparedness and engagement, deep understanding, and communication of mathematics have for many years challenged university mathematics/statistics educators.

For the last decade, the authors have faced these challenges and have explored the use of various digital technologies to support mathematics and statistics learning and teaching in face-to-face and online environments. In particular, we have investigated the use of tablet PCs[1] to enable effective mathematical communication through electronic handwriting. In addition, we have developed and evaluated various forms of screencasts[2] to support mathematics/statistics learning.

This chapter first outlines the challenges related to teaching in quantitative disciplines (e.g. mathematics, statistics, engineering, science and economics) in on-campus and online environments. It is followed by an analysis of the contribution our decade of published and unpublished research has made to resolve these challenges. In so doing, we highlight a phased cycle of innovation (i.e. conceptualising, implementing, evaluating, and reconceptualising), and report on the impact of the work on learning and teaching across different environments. Finally, the chapter provides an overview of innovations that have worked and are still successfully used, and others that did not proceed beyond trial status. Unsuccessful trials are rarely reported, but we make an exception here as they are an integral part of this innovation cycle.

Issues

Teaching mathematics and statistics in the 21st century is challenging. Educators face the interrelated issues of under-prepared and disengaged students, lack of students' deep understanding of concepts, and difficulties in establishing meaningful two-way communication between students and teachers, particularly in online environments. These three issues are now discussed.

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[1] Tablet PC: A laptop computer with or without fixed keyboard that has an LCD screen to write on with a stylus. Usually runs on a Windows operating system. (http://www.webopedia.com/TERM/T/tablet_PC.html

[2] Screencast: A screencast is a digital video recording that captures actions taking place on a computer desktop and narrator audio. (http://whatis.techtarget.com/definition/screencast)

Preparation and Engagement

With the deregulation of the Australian higher education sector, a significant proportion of students entering university come from diverse educational, social, and economic backgrounds (Department of Industry Innovation Science Research and Tertiary Education, 2012, 2013). Similarly to studies from the UK (Croft, Harrison, & Robinson, 2009), universities in Australia report increasingly varied levels of mathematical preparedness for university study. Rylands and Coady (2009) and Varsavsky (2010) highlighted that mathematical under-preparedness is now more prevalent and report significant impact on student performance. In a report on school to university transition, James, Krause and Jennings (2010) suggest that while half the students surveyed felt school had prepared them well for university, "this was not the case for students from rural areas and those from lower socio-economic backgrounds" (p.33). They argued that "there continues to be a disparity in the level of university preparedness of students from certain demographic subgroups" (p.33). While increased participation of students from such backgrounds is a step forward for inclusiveness, this also presents challenges. Lyons, Cooksey, Panizzon, Parnell, and Pegg (2006) reported that such locations have the most difficulty attracting and keeping good quality science and mathematics teachers.

In addition to issues associated with socio-economic and geographic disadvantages, many students, enrolling in science- and engineering-based programs, lack necessary mathematics skills. Evidence indicates that students are taking lower levels of mathematics at school (Barrington, 2012) and do not regard it as fun or interesting. In a study undertaken in Victoria, almost 40% of Year 9s found mathematics difficult (Victorian Auditor-General, 2012). Many students also hold a belief that mathematics is not necessary for science (Matthews, Adams, & Goos, 2009). Outside of science, many students who study subjects with some mathematical and statistical content, or assumed knowledge(e.g. history), struggle to understand concepts that require quantitative reasoning (Freeman, 2010). It is not surprising that students studying mathematical content at university often express fear and anxiety (Parsons, Croft, & Harrison, 2009).

We ask the question: How then can we support and engage students in quantitative subjects?

Understanding mathematics concepts

Understanding a concept is more than knowing. It is about the "why" and "how"; an ability to describe thinking; and being able to represent concepts in different ways. Students need both an instrumental and relational understanding of the concepts (Skemp, 1976). Students need to have instrumental understanding (that is, knowing *that* something is true and knowing *how* to do it), particularly if they are applying mathematics and statistics to other areas such as engineering, nursing, business, and science. However, they also need relational understanding, that is, knowing *why* something works and knowing *to* use it in appropriate situations (Mason & Spence, 1999). Engaging students in face-to–face mathematics classes in such circumstances is difficult, although, with the benefit of visual cues and strategies, it is possible to adjust teaching to the levels of understanding of the audience. For example, Taylor and McDonald (2007) used group work and writing to enhance mathematical problem solving. However, teaching to a diverse audience with varying levels of mathematical knowledge, in an online environment, is more difficult, and lecturers in these environments struggle to ensure their students acquire understanding.

We ask the question: How then can we expand students' ways of knowing, i.e. knowing-how; knowing-that; knowing-why and knowing–to?

Communicating mathematics

Teaching and learning of mathematics and statistics is challenging when lecturers and students are separated in space and time. It is particularly important to keep students engaged when there is no regular interaction with the content, with other students, with the lecturer, and the e-learning system (Bouhnik & Marcus, 2006). However, engagement is more difficult to facilitate in mathematics because of the visual nature of the content (Maclaren, 2014; Smith & Ferguson, 2004). How do you effortlessly explain the shape of the standard normal curve or show how to factorize a quadratic equation in an online environment? What is needed are technologies that allow for immediate and seamless interaction no matter where the student is located. Such technologies need a sustained and supportive infrastructure so that these are easily and routinely accessible for staff and students. Too often technologies such as tablet computers, are too expensive or too reliant on IT support and expertise to be rolled out in large first year university subjects. Finally, to engage deeply in mathematical learning, students need to be ready and willing to expose their relational, instrumental and metacognitive understandings to others (Galligan, Hobohm, & Loch, 2012).

Mathematical and statistical discussion requires visual communication of symbols and diagrams. In online learning, this communication is facilitated entirely by technology. Communicating via diagrams and formulae needs to be a straightforward task (Loch & McDonald, 2007) and requires an enabling platform. Entering mathematical notation into the computer needs to be easy and natural for students and teachers alike. Loch and McDonald (2007) suggest that teaching distance students can be a frustrating experience due to limitations of the medium used in two-way discussions, particularly when engaging in collaborative problem solving. The researchers were seeking was a "conducive environment for active learning and interaction" where the environment facilitates "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" (Galligan et al., 2012, p. 368).

We ask the question: How then can seamless bi-directional communication be achieved in an online context?

Innovative solutions

The three questions posed in the previous sections can be addressed by innovative use of tablet technology and screencasting. The tablet PC was released more than a decade ago and slowly emerged as a tool to support learning (Cicchino & Mirliss, 2002); with the technology becoming ubiquitous over the last three years. Tablet-related technologies have the potential to revolutionise teaching in quantitative disciplines.

What distinguishes a tablet PC from a laptop computer is the touchscreen that takes input from a stylus to enable the user to write on or manipulate the screen. University teachers have used them to enhance their lectures in engineering, mathematics, computing, and chemistry (Al-Zoubi, Sammour, & Qasem, 2007; Loch, 2005; Loch & Donovan, 2006; Olivier, 2005). Researchers claim that using the tablet PC in carefully designed ways can have positive effects on student attention and learning (Hojjatie, Hooshmand, Leader, Brevik, & Groszos, 2008; Wise, Toto, & Lim, 2006). Particularly, it allows teachers to focus on the essence of concepts and their development, and less on often-overwhelming, static, polished content. Effective use of the tablet PC has also been shown to increase engagement in the classroom (Anderson, Annand , & Wark, 2005; Logan, Bailey, Franke, & Sanson, 2009); and communication with online students, allowing both teachers and students to use electronic handwriting in the pursuit of knowledge and skills (Loch & McDonald, 2007).

Screencasts have been described as “folksy, intimate experiences that feel as if you were sitting shoulder-to-shoulder with a friend” (Kanter, 2007 para. 9), and are able to “humanise the presentation of mathematical reasoning” (Loch, Jordan, Lowe, & Mestel, 2014, p. 265). Sugar, Brown, and Luterbach (2010) suggest that screencasts were originally developed to provide procedural information to students. Many of today’s students studying mathematics at university have access to recordings/screencasts in their subjects or on the web. These offer a multitude of explanations for basic to high level mathematical and statistical concepts. Increasingly, screencasts today are being developed taking pedagogical issues into consideration (Heilesen, 2010; Loch & McLoughlin, 2011). The focus of many such recordings, however, still appears to be more on procedural rather than any other form of mathematical or statistical understanding; yet screencasts have the potential to do much more (Galligan & Hobohm, 2013).

To explore the issues of student under-preparedness, fostering deeper student understanding and communication of mathematics, the next section provides an analysis of the authors’ previous research into innovative uses of tablet technologies. Rogers (2003) developed a five stage decision process for innovation: knowledge, persuasion, decision, implementation and confirmation. This process begins when an individual becomes aware of a potential innovation (awareness knowledge), what it currently does (how-to knowledge), and how it will work in a specific context so as to avoid misuse (principles knowledge). This is followed by the persuasion stage where the individual considers the innovation in relation to his/her context, discussing the possibilities with others. The decision stage includes experimentation with the innovation and ultimately a decision on whether to adopt or reject the innovation. If the decision is to adopt, implementation takes place. Finally confirmation is sought on whether to continue with or abandon the innovation. We resituated these in our educational setting (Figure 1) to formulate an innovation-development cycle.

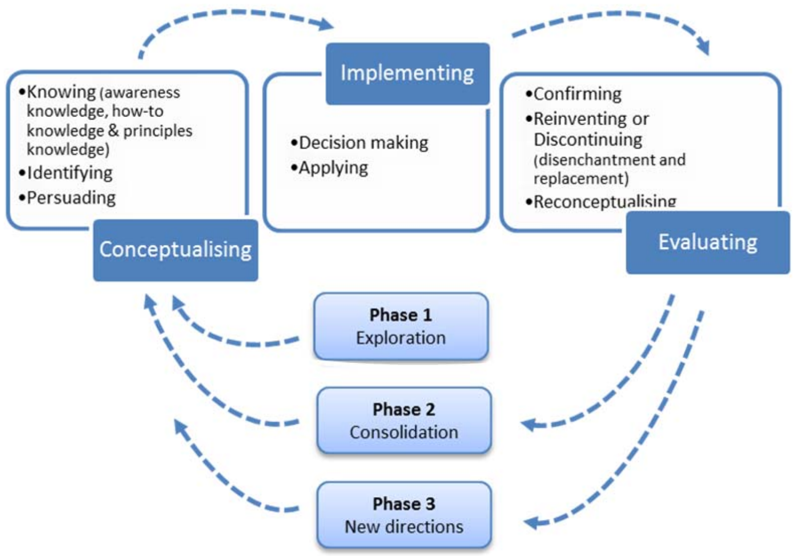

Figure 1: Innovation-Development Cycle

We therefore divide our investigations into three distinct phases: exploration, consolidation and new directions, all of which form part of the innovation-development cycle. Central to these phases is the innovative use of digital technologies specifically to enable the user to handwrite mathematics on a screen and share across the online education medium.

Phase 1: Exploration

"Innovation-development occurs as people talk, when information is exchanged about needs, wants and possible technological solutions to them" (Rogers, 2003, p. 144). This statement succinctly describes phase 1 of our research from 2004 to 2007 (Figure 2). During this time, much discussion occurred around the particular needs of engaging, preparing, communicating, and understanding mathematics. In this section, we take you on a personal journey describing incidents that allowed us to surge ahead with exploring innovative solutions, highlighting the conceptualisation of the problems, implementation of possible solutions, formulation of a framework, and reflection on those that worked well and those that did not.

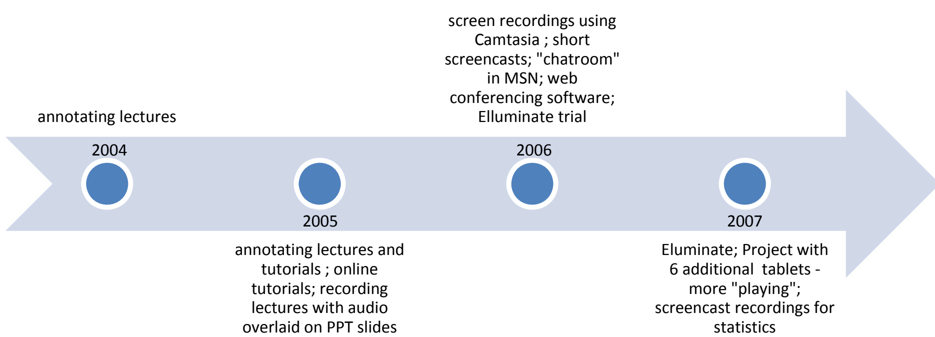

Figure 2: Timeline of Phase 1

Conceptualisation

The authors have all worked in a university where 80% of students are enrolled externally, and the problem of effective mathematics/statistics teaching and learning had been recognised since 1975 when the university strenghted it's distance learning mode of delivery. Many students were (and still are) underprepared and anxious, but needed to understand the mathematics that bewildered them in highschool, as well as the university mathematics content they are currently studying. In the early 1990s, Janet and Linda used audiographic technology[3] in mathematics tutorials (Harman & Dorman, 1998; J. Taylor & Morgan, 1996), and observed how multi-directional communication with geographically dispersed students could assist learning. We talked to students whilst writing on a digital whiteboard, and they could talk and write back in real time. However, this technology required a high level of IT support. Students needed to be available at the designated time and be willing to travel to a study centre; and teaching staff had to be willing to spend time developing the skills to use the technology (see Figure 3). Janet and Linda routinely used this technology, however the unreliability and cost of the technology, the costs of staffing study centres at night and the difficulty in attracting large numbers of students to defined locations at set times saw the demise of the system in the early 2000s.

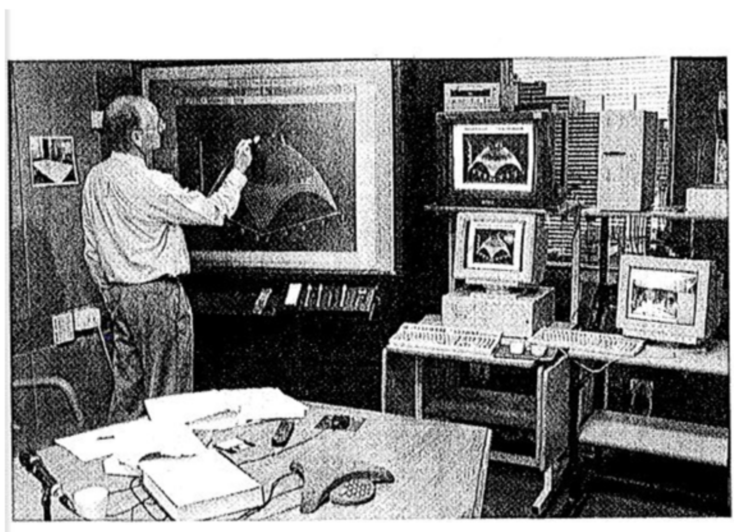

Figure 3: Using a Smart2000 board in the 1990s's (Harman & Dorman, 1998, p. 306)

In 2004 Birgit experimented with a graphics tablet[4] lent to her by a colleague when a lecture theatre refurbishment had removed her capacity to simultaneously show computer slides and write on overheads. Birgit started to experiment with further possibilities using a tablet PC

[3] Including a desktop videoconferencing system, electronic whiteboards and conferencing software and Polycom teleconference phones

[4] Graphics tablet: A stylus based input device for the computer, allowing electronic writing.

(Loch, 2005), encouraging colleagues to do the same (Loch & Donovan, 2006). When Birgit commenced work with Linda, Chris, and Janet, she brought 'awareness-knowledge' of tablet technology and 'how-to knowledge' of using this technology for handwriting electronically (Rogers, 2003, p. 173).

The possibilities of using the tablet in distance learning quickly began to emerge (Loch & McDonald, 2007; Reushle & Loch, 2008). A dynamic partnership was formed between instigator (Birgit) and enthusiastic early adoptors (Chris, Linda and Janet), who added the third type of knowledge about innovation, "principles-knowledge" (Rogers, 2003, p. 173), in both learning and teaching, and mathematics and statistics education, i.e. the pedagogical understanding of how this technology may be used specifically in an online learning environment.

Implementing

We were keen to apply our newfound knowledge particularly to first level undergraduate subjects, where student numbers can be in the hundreds, backgrounds were varied and therefore the need to improve mathematical understanding and communication was the greatest. As well as Birgit's tablet PC, the purchase of inexpensive graphics tablets enabled us to trial and compare the use of electronic handwriting in a number of quantitative subjects. We also started using recording technologies (Camtasia Studio[5]) and interactive platforms (MSN messenger[6] with electronic handwriting). A successful grant application gave us the impetus to trial a myriad of applications with tablet PCs to support students, especially those studying at a distance. We were able to explore, within our teaching, the benefits of conferencing and communication tools, multimedia elements, electronic handwriting, and recordings to support learning. These included complete lecture recordings which were then made available to distance students and shorter targeted screencasts. In addition, we utilized electronically handwritten emails; created exam preparation recordings; implemented electronic marking of assignments; and developed collaborative in-class exercises with a tablet connected wirelessly to a projector for students to use. Our reach included teaching one-to-many (lectures), one-to-few (tutorials, online asynchronous discussions and online synchronous tutorials) and one-to-one (learning support and personal communications), highlighting critical points of conceptual difficulty where students get "stuck" and fail to move forward in understanding in mathematics and statistics (Galligan, Loch, McDonald, & Taylor, 2010). Heady days (and nights) were the norm, with each team member bringing with them different types of knowledge (awareness, how-to, and principles).

Evaluating and Reflecting

By the end of 2007, ten staff were using tablet technology and related software (Loch & Fisher, 2010), and their teaching involved over 2000 students across six subjects from a range of disciplines. At this stage we employed an action research methodology taking an exploratory approach and focussed on the teachers' uses of the technology. We collaboratively reflected on our own innovative practices, adapting and assessing their effects as we progressed

[5] Camtasia Studio software is used to record on-screen activity, edit content, add interactive elements, and share videos (http://www.techsmith.com/camtasia.html)
[6] MSN messenger is a free instant messaging software licensed by Microsoft in 1999 and runs under Windows operating system. (http://en.kioskea.net/faq/123-msn-messenger)

(Marshall & Rossman, 1999). Our publications at the time highlighted what we did, and how we evaluated the impact of the technology using teacher observations (Loch, 2005), unsolicited student emails, formal feedback surveys (Loch, 2005; Loch & Donovan, 2006; Loch & McDonald, 2007) and analysis of student activity (Loch & McDonald, 2007). Importantly students liked our approach:

> *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 (student response from MSN messenger trial)* (Galligan et al., 2010, p. 46)

However, not all trials were fully published. For most of these trials data were collected, but studies were not written up due to lack of time or because the trials were unsuccessful. For example, an experiment was set up in 2006 which four of the authors offered weekly tutorials online in a first level mathematics subject using MSN Messenger. This aimed to mimic the face-to-face approach undertaken by Taylor and McDonald (2007) in an online situation. Students reported that they gained confidence in seeking assistance and from seeing other students' explorations and ideas; and they felt less isolated. The sessions were seen as easy and motivating and kept students on track (Galligan et al., 2010). One student commented that "the online mechanisms are fantastic - a whole new thing to me the tablets are a God-send". In another (unpublished) trial in 2005, a CD with lecture recordings had been prepared and sent to distance students to limit download requirements. Again students reported the usefulness of this strategy especially for revision.

For the innovation to be sustained, we needed to get more staff to embrace the use of tablet-related technologies in their teaching (Rogers, 2003). However, there were still issues that required attention. These included the reliability and ease of use of the technology; the limitations of the small writing area of a tablet PC screen compared with large whiteboards; students' hesitancy to use the technology if handed a tablet on which to write; and awkwardness of using some of these technologies, such as pen size (Galligan et al., 2010). Despite these issues we were sufficiently convinced that this technology had potential to support and engage the learner and to improve communication. While we believed it could capture "clear and recordable mathematical thinking in action"(Galligan et al., 2012, p. 50), the technology needed to be more intuitive and we needed more insight into how to facilitate student understanding in the online environment. We needed to increase our knowledge; persuade more people that there was potential for this to really improve teaching and learning; and have a broader implementation and evaluative framework. Through Birgit's formal and informal "interpersonal channels of communication" (Rogers, 2003, p. 205), two university-based learning and teaching fellowships were awarded, giving us an opportunity to move the innovation to the next phase.

Phase 2: Consolidation

This phase was characterised by a move to mainstream tablet technology. We further explored student use of the technology, and established a theoretical framework of active and collaborative learning that helped convince us, and others, that tablet technology was worth pursuing. At this stage, both Linda and Chris were working towards their doctorates in mathematics and statistics education respectively, and their developing knowledge in this area contributed to our re-conceptualisation of the affordance of the technology to support student learning of mathematics and statistics.

For instance, Chris expanded on the original MSN messenger trial by using virtual classroom collaboration software to conduct synchronous, interactive tutorials online, to engage distance students and investigate how interaction in the tutorials contributed to the learning and teaching of statistical concepts. She used the Community of Inquiry Framework (CoI) (Garrison, Anderson, & Archer, 2000) to gain a deeper understanding of the dynamics of interactions taking place in this collaborative learning environment by investigating the contributions of teaching presence, cognitive presence and social presence, particularly in relation to the development of problem solving skills (McDonald, 2013). These three presences of the CoI have been shown to interact by setting the climate, regulating the learning, and supporting discourse to create the educational experience. Around the same time, Linda was using Human Development Theory (Valsiner, 2007) to investigate learning change issues experienced by adults learning or re-learning mathematics at university (Galligan, 2008, 2011). The theory is based on developmental psychology where three aspects of human development are investigated: that people develop in an environment in the contexts of every day actions; that when activity occurs, people can reflect on their actions; and that the experiences of the person can "transfer to the general life course development of the person" (Valsiner, 1997, p. 168). The investigation focussed on short episodes of learning captured in screencasts, where both the student and the teacher shared the same tablet and the interactions were recorded via Camtasia Studio.

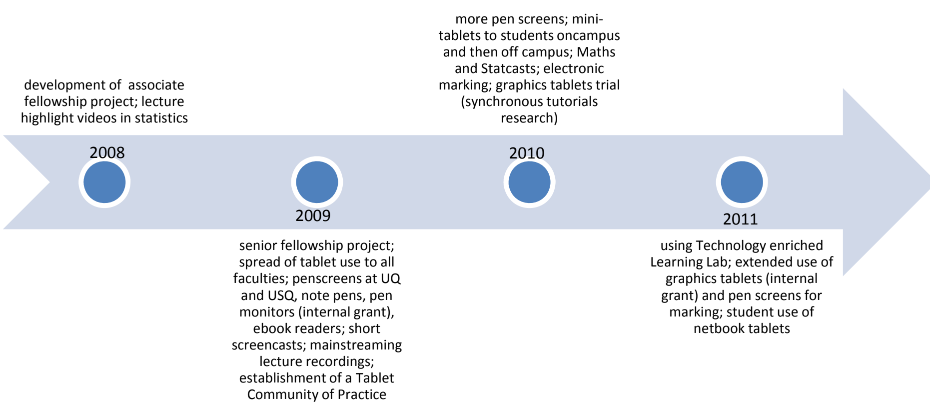

Figure 4: Timeline of Phase 2

Reconceptualising

The fellowship projects and grants (Figure 4) were designed to systematically trial and evaluate the emerging technologies. In this phase, we looked for an approach that focussed on the learner rather than the teacher, and that promoted active learning (Loch, Galligan, Hobohm, & McDonald, 2011). Emerging research suggested that tablet PCs could support active learning (Cromack, 2008)and we found that using such an active learning framework around the learner redirected some of our research. While the second fellowship project was originally meant to include only staff tablet PCs, additional funding allowed the purchase and trialling of 30 netbook[7] tablet PCs for students in 2010. This component of the fellowship also allowed Birgit to concentrate on consolidating the implementation and evaluation of the technology, and to bring in a fifth member of staff (Carola) to act as another ‘change agent’, that is, she facilitated the uptake, diagnosed problems, and stabilised the adoption of tablet technology (Rogers, 2003, p. 173). Carola joined with a dual role as Technology Mentor and Project Officer thus bringing training experience and IT support skills (how-to knowledge).

Implementing

By 2010 the University had adopted Camtasia Relay[8] as its lecture recording technology (Loch, 2009) and interactive pen displays[9] were introduced in four classrooms. Camtasia Studio was still being used to create screencasts for our subjects (Loch, 2012). Additional tablet PCs were purchased, allowing lecturers in other disciplines to trial the technology for both teaching and marking, usually with support from Birgit and Carola (Brodie & Loch, 2009; Goh, Galligan, & Ku, 2013; McCabe & Hobohm, 2012; Phillips & Loch, 2010; Wandel, 2009, 2010). There was considerable interest in tablet technology in the wider academic community and this interest was supported by a Community of Practice with 87 participants, where, in an informal setting, academics were encouraged to share their experiences of incorporating tablet technology into their teaching.

During this period a number of further trials were launched, which focused on encouraging student action with tablets. The netbook PCs were evaluated for their viability for student use compared with full-size tablet PCs (Loch et al., 2011). Despite some disadvantages such as processor speed and screen size, student and teacher responses to the netbooks encouraged us to expand the original on-campus trial to distance students (Galligan et al., 2012). Overall, we found that students needed improved input devices to provide better user experiences than the netbooks. Thus a graphics tablet was trialled with one student who found the graphics tablet was easier to install and use, and enabled him to share his difficulties in conceptual understanding.

In 2011 we trialled 12 graphics tablets with first year distance mathematics students. Most of this work is unpublished, but it suggested potential for students to create and then submit handwritten assignments electronically; one student said it was “much more convenient than scanning and emailing”. We also saw potential for students to use this device to display electronically what they were thinking. However, at this stage, an investigation, by Galligan, Wandel, and Hartle (2011) found that students appeared to be unwilling or unable to express their thinking regardless of the technologies.

While we were investigating the online environment, we also investigated how in-class interactivity could be improved using software that allowed teachers to share content on students’ tablets with the class (Donovan & Loch, 2013). The literature suggested potential for widespread use in the school environment (Reed & Berque, 2010). We trialled a collaborative

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[7] Netbook PC: A small, lightweight, inexpensive computer.
[8] Camtasia Relay: The server based lecture theatre version of Camtasia Studio to record lectures. http://techsmith.com/relay
[9] Interactive pen display (pen-screen): Monitors with touch-sensitive surface for writing on the screen with a stylus.

classroom management software program, but issues with wireless connectivity and institutional IT support restricted its use and success. We continued to engage students to use wirelessly connected tablets and share their work during lectures or tutorials. The evidence appeared to indicate that this practice encouraged classroom discussion, particularly around errors or understanding of concepts (Galligan et al., 2010). Still, for it to become normal practice it needed to have institutional support and stable wireless connectivity.

Evaluating and Reflecting

We continued our action research approach (Loch & Fisher, 2010, p. 550) and captured students and staff views and experiences through purpose-designed surveys and routine subject-based student feedback questionnaires. For the netbook tablet projects, evidence was found of both active learning and collaboration, but varied depending on subject content, learning space, tutor, teaching style, and type of collaboration (Loch et al., 2011). Interestingly, comparing the on-campus and online experiences of students, we observed that the way the tablet technologies were used varied considerably between the two groups. We concluded that understanding the student and their different learning environment (physical, social and emotional) and expectations is critical to success (Galligan et al., 2012). For example, online students had particular difficulty in using technology despite the support offered, and many students had high, mainly unfulfilled, expectations to write legibly to an acceptable standard using the tablet devices. On the other hand, these students acknowledged the value of netbooks for communicating mathematically, particularly for assignment submission, and recognized the potential for easier interaction with content and the lecturer. Students and staff acknowledged an enhanced feeling of humanness when using this technology (Nooriafshar, 2011; Wandel, 2010).

For screencasting, the evidence suggested that screencasts removed the need to have repeated exchanges between students and instructor (Loch, 2012). While annotated lecture recordings continued to be useful for both on-campus and online students, the provision of shorter concept-specific screencasts appeared to serve a different purpose. One student commented, "*to be honest, without these online screencasts, I would not have understood concepts or passed this course*" (Loch, 2012, p. 50).

Other evaluations included (unpublished) surveys of lecturers using tablet technology. While we did not formally evaluate the use of pen screens for lectures, tutorials or marking, many of these devices have now been purchased and become standard fixtures in lecture theatres to afford lecturers digital whiteboard capabilities. In addition, with over 90% of students submitting assignments electronically, many lecturers now also use tablet PCs or pen screens for marking:

> *I'm now completely sold on the idea - I could cross out, add stuff in, use the eraser should I change my mind mid-thought and the like. The only thing I didn't try was to spill my coffee on the assignments (Science lecturer 2009).*

At the end of Phase 2, we had some evidence that the technologies trialled and used had benefited student engagement and understanding.

Phase 3 – new directions?

We are now in a new phase of the innovative use of tablet technologies with the main focus on students using tablets to explain and reflect on their own learning whilst we continue to investigate emerging tablet technologies. This phase is characterised by the development of a theoretical stance and the dissemination of research outputs associated with teacher and student learning.

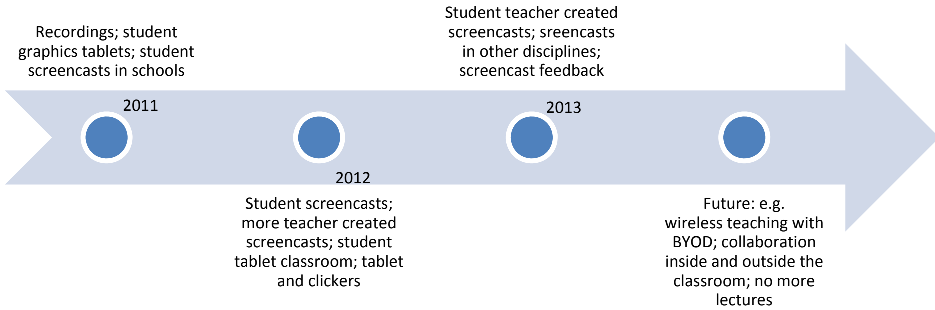

Figure 5: Timeline of Phase 3

Linda and Carola have recently reported on research of pre-service teacher and teacher-produced mathematical screencasts (Galligan & Hobohm, 2013), which displayed promising results in capturing cognitive and metacognitive processes. The aim was to motivate students to think aloud whilst capturing their cognition during screencast recordings, thereby showing how they solved mathematics problems. The screen captures would assist lecturers marking the correctness and appropriateness of the mathematics explanation, as well as helping education students to reflect on their and their students understanding of mathematics. However, even with the technology working, other issues arose, as one student reflected: “I first must say that I was absolutely terrified at doing this, not the math writing part but the talking part. For a couple of days I would sit down to do it, but lost all my nerve…” (p. 328).

Meanwhile, Birgit armed with extensive implementation and strategic knowledge introduced the use of tablets and wireless teaching[10] at her new university to investigate student tablets as well. Her research now focusses on student-produced screencasts to enhance teaching material (Croft, Duah, & Loch, 2013) and to motivate the relevance of mathematics to first year students (Lamborn & Loch, 2013). She is investigating the impact of screencasts on student performance (Loch et al., 2014) and student perceptions (Loch, Gill, & Croft, 2012; McDonald, Dunn, Loch, & Weiss, 2013). She is also looking into video feedback in mathematics, teaching strategies built on a BYOD (bring your own device) philosophy and a faculty-wide implementation of blended learning where traditional lectures are reduced to a minimum.

[10] Wireless teaching: Projecting wirelessly to an overhead projector, for example to allow collaborative teacher-student interaction.

The team has now turned their attention to effective design of screencasts (Galligan & Hobohm, 2013; Loch & McLoughlin, 2011, 2012) where we make purposeful links between deep understanding of mathematics and the design and delivery via screencasts.
Phase 3 is moving to conceptualising the innovative use of tablet technology in mathematics and statistics again. We may need to look to new types of knowledge, particularly around student-focussed considerations. In the implementation we need to consider how students can access such technologies easily, and in evaluating we need to consider what are the technologies that are most student-friendly.

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Conclusion and Future Directions

This chapter chronicles the journey of five mathematics/statistics educators as they embarked on a voyage of discovery which explored the use of a range of new tablet technologies and the impact on teaching and learning. This journey highlights the well-known and specific challenges of teaching quantitative disciplines such as mathematics and statistics, especially in online environments. It showcases tablet technologies as an innovative solution to the challenges posed by changing educational environments and student preparedness. A reflection on our research highlighted a series of approaches in an innovation development cycle which included conceptualising, identifying, evaluating and reconceptualising. The chapter highlighted innovations that have worked and are still successful, such as pen screens for lectures, tablet devices for electronic writing and marking, and production of screencasts by lecturers. It should also be acknowledged that some innovations, such as netbook tablets, were discontinued. A few of the technologies we used early on, such as MSN chat, are now superseded by interactive online collaboration platforms such as Blackboard Collaborate™. Tablets and smart phones with touch input have become ubiquitous, however tablets with a stylus suitable for accurate writing have not. Uptake for a large cohort of online students is therefore still a challenge, as cost, technological know-how and access to the technology remain issues. In addition, some dissatisfaction with technology performance has been reported by both lecturers and students, which could be attributed to the lack of institutional support, lack of lecturer time, lack of resources, or differing beliefs by lecturers of its usability or usefulness (Corcoles, 2012; Musarrat, Loch, & Williams, 2013).

The three questions advanced in this chapter have been addressed in our research, both published and unpublished, across the three phases of innovation. In this research, there is evidence to show that the technologies we investigated improved support and engagement, fostered understanding, and enhanced multi-directional communication. Our story may help others addressing similar challenges with ideas and strategies for their future practice. However, for us as digital technologies improve alongside learning designs, questions continually arise on how to capitalize on innovative functionalities. The journey continues.

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