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Technology in teaching: A case study at a mathematics department at a research intensive university in South Africa

by

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Declaration by Student

I, the undersigned, declare that this dissertation, which I hereby submit for the degree Magister Scientiae at the University of Pretoria, is my own work and has not previously been submitted by me for a degree at this or any other tertiary institution.

Signature:

Date: 8 December 2014

The undersigned certify that they have read, and recommended to the Faculty of Natural and Agricultural Sciences for acceptance a dissertation titled "Technology in teaching: A case study at a mathematics department at a research intensive university in South Africa" submitted by Anneli Billman in partial fulfilment of the requirement for the degree Magister Scientiae: Mathematics Education in the Faculty of Natural and Agricultural Sciences at the University of Pretoria.

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ABSTRACT

In order to meet the changing needs of today's students and society, instructors need to adapt to new teaching methods. The purpose of this case study is to explore the integration of technology into teaching at a mathematics department at a South African University. Questionnaires were completed by staff lecturing undergraduate mathematics and both quantitative and qualitative data were collected in this survey. Selected interviews were conducted with respondents to obtain richer data.

The study shows that half of the staff members feel that chalkboards are more suitable than technology for teaching mathematics. This finding supports the idea of a strong subject culture. Age did not emerge as a factor for preference of either technology or the chalkboard, although gender, academic qualification and teaching qualification did. Subject culture is strongly rooted under the male members of staff, while female staff felt more positive towards the use of technology for teaching. The higher up in the ladder of academic qualifications, the stronger the belief in the chalkboard for teaching. Teaching qualification indicated a preference for technology for teaching. Use of chalkboards decreased significantly over the past ten years, while the use of modern technologies has increased accordingly. Teaching of large groups has necessitated the use of technology. A shift in attitude towards technology use in teaching is perceived. There is a trend of moving towards using new technologies. The study showed that the majority of teaching staff make limited use of the LMS. The use of other technologies as a learning tool for students was found to be limited amongst staff.

Teaching staff at this department do integrate technology into their teaching, and therefore practise blended teaching. However, many of the benefits offered by technology are underutilised and the use of technology does not necessarily lead to improved learning.

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LIST OF ACRONYMS AND ABBREVIATIONS

CE@UP	Continuing Education at University of Pretoria (Pty) Ltd
CRQ	Constructed Response Questions
DMAM	Department of Mathematics and Applied Mathematics
EEB	Electronic-Exercise Base (e-exercise base)
GUI	Graphical User Interface
ICT	Information and Communications Technology
IWB	Interactive Whiteboard
LMS	Learning Management System
MCQ	Multiple Choice Questions
PLE	Personal Learning Environment
PLN	Personal Learning Network
PRQ	Provided Response Questions
SARChI	South African Research Chairs Initiative
UP	University of Pretoria

DEFINITIONS

Credit

One credit in the SAQA credit system equals 10 notional hours of learning. 'Notional hours of learning' is the time that it would take an average learner to meet the defined outcomes and includes contact time or time spent in structured learning (in the workplace), individual learning and assessment (Isaacs, 2000).

Electronic boards

An electronic board is a large, touch-sensitive board; it controls a computer connected to a digital projector. Electronic boards offer many of the advantages of using chalkboards, together with the advantages of modern technology, such as saving, printing or sharing the material written on the board.

Tablet (mobile tablet)

A tablet is a mobile computer, a single unit consisting of a screen, circuitry and battery. Tablets come equipped with a touchscreen using finger movements and/or a stylus for input instead of a mouse or keyboard - an on-screen, pop-up virtual keyboard is usually used for typing.

Tablet PC

A tablet PC is a notebook (laptop/portable computer) with a touch screen (the capability of using the screen for input) and is usually furnished with a stylus for writing on the screen.

Blackboard

Blackboard, the Learning Management System (LMS) used by the University of Pretoria, is a virtual learning environment and course management system. Online elements can be added to courses that are traditionally delivered face-to-face; and courses can be developed that are delivered entirely online.

CAMI Maths

CAMI Maths is an educational software system which allows students to master mathematical skills in a progressive, incremental manner. The syllabus covers pre-school to grade 12. Students receive immediate feedback and positive reinforcement. CAMI Maths can be used for diagnosis, practice and remediation purposes as students' progress is continuously monitored and recorded.

MATLAB

MATLAB is a high-level language and interactive environment for numerical computation, visualisation, and programming. With MATLAB, data can be analysed, algorithms developed, and models and applications created. Multiple approaches can be explored.

WebAssign

WebAssign is a flexible online instructional system that accompanies Cengage Learning textbooks. WebAssign provides assessment, an extensive textbook selection and support, and enhances student learning. It allows the lecturer to create assignments which instantly assess individual students and whole class performance. WebAssign provides Learning Management System (LMS) integration for Blackboard.

CHAPTER 1: INTRODUCTION TO THE STUDY

1.1 Background and rationale

Skills shortages in South Africa are considered to be a key factor for the country not achieving a growth rate of six percent. These shortages exist due to a number of issues – including the country's apartheid history, post-apartheid attempts to rectify imbalances and a global market for professional skills.

Critical skills refer to key (generic) skills and particular skills required within an occupation that might have arisen as a result of changing technologies. Key (generic) skills include cognitive skills, language and literacy skills, mathematical skills, information and communications technology (ICT) skills, and team-work skills.

Our current mathematics, science and technology education is often not adequately adapted to a world transformed by scientific and technological advances. Familiarity with the basic concepts of mathematics, science and technology is necessary for critical thinking and making informed decisions in the work place, and about both personal and social issues. As many routine tasks become computerised, jobs require higher level skills, including critical thinking and problem-solving skills, that are developed through high-quality mathematics, science and technology education. As the world evolves, the critical skills required evolve.

Furthermore, situations at higher education institutions in South Africa have dramatically changed over the last 20 years due to larger student numbers and larger classes. Students are also evolving – today's students grew up in a technological age and tend to interact differently with information than students 20 years ago. Hellen Keller said:

> A bend in the road is not the end of the road, unless you fail to make the turn.

In this context, if instructors continue to teach as they have done during the past two decades, they run the risk of failing to produce graduates with skills necessary to meet the job market. In order to meet the changing needs of today's students and society, instructors need to adapt to new teaching methods. A blended teaching approach that combines traditional face-to-face teaching with various technologies, utilizing the advantages of both these components, is necessary. Technology can be integrated into the classroom, and online components added to courses traditionally delivered face-to-face.

However, many instructors are not proficient in integrating technology into the classroom and display resistance towards the integration of digital tools. This seems to be true especially for instructors in mathematics. Although it can be challenging, there is a growing need for instructors to understand how the use of these digital tools can add value to their teaching and benefit students.

The purpose of this case study is to explore the integration of technology into teaching at a mathematics department at a South African University.

1.2 The Department of Mathematics and Applied Mathematics at the University of Pretoria

The University of Pretoria was founded in 1908. At the time, mathematics and physics formed one department. The Department of Mathematics was initiated in 1912, while applied mathematics was still part of the physics department. In 1941 the Department of Applied Mathematics was established and these two departments merged in 1986 to become the Department of Mathematics and Applied Mathematics.

The Department of Mathematics and Applied Mathematics offers approximately 41 undergraduate mathematics modules and 16 modules at honours level per year. During 2014 there were more than 20 000 enrolments in mathematics modules in the department.

During the first semester of 2014, the academic staff of the Department of Mathematics and Applied Mathematics totalled 77 (44 full-time and 33 part-time). The academic staff consisted of 11 professors, five associated professors, ten senior lecturers, 19 lecturers, four junior lecturers and five senior technical assistants (accredited as lecturers). Two post-doctoral fellows and 21 assistant lecturers (post-graduate MSc and PhD students) were appointed on a part-time basis and were mostly involved in tutorial classes and the grading of assignments and tutorial or class tests. Excluding the 21 assistant lecturers and two post-doctoral fellows, 19 of the academic staff were female, and 35 male. The senior technical assistants accredited as lecturers, with the exception of one, did not have teaching duties.

Of the 54 academic staff members, 41 had South African nationality. Approximately six members of the academic staff were under 35 years of age, 18 in the category of 35 years to 49 years, 23 in the category of 50 years to 65 years, and seven in the category above 65 years.

Included on the staff list were the dean of the faculty of Natural and Agricultural Sciences and the SARChI chair in Mathematical Models and Methods in Bio-engineering and Biosciences.

1.3 Research aims

The primary aim of this research is to determine the status quo of the use of a blended learning approach by the teaching staff of a mathematics department at a research intensive university in South Africa for teaching undergraduate mathematics. The Department of Mathematics and Applied Mathematics at the University of Pretoria (UP) was used as a case study. The secondary aim is to address some of the attitudes, beliefs and perceived barriers that inhibit the implementation of technology.

The researcher does not intend to evaluate the quality of the teaching of mathematics, nor seek to suggest that teaching with the use of modern technology is necessarily superior to teaching without technology.

1.4 Research questions

In order to explore the blended approach followed by the lecturing staff at the Department of Mathematics and Applied Mathematics at UP, both inside the classroom and outside the classroom, the following research question is posed:

> **To what extent is a blended teaching approach currently used by lecturing staff for teaching mathematics at undergraduate level?**

1.5 Research sub-questions

The following sub-questions are posed in order to direct the exploration of the research question.

1. What are the attitudes and beliefs of the teaching staff with respect to the suitability of using technology for teaching mathematics?
2. What technologies do the teaching staff prefer to use? To what extent are these technologies used when lecturing undergraduate mathematics inside the classroom? How has this changed over the last ten years?
3. Do the teaching staff make use of the learning management system (LMS) as a tool for administration and communication purposes as well as for academic purposes? Do they use any other technologies as a tool for learning outside the classroom?

1.6 Framework

This dissertation consists of seven chapters. Chapter two reviews literature on blended teaching and teaching technologies. Chapter three focuses on the development of an instrument to measure the technological proficiency of the participants. Chapter four describes the research methodology applied in this study.

Chapter five offers a discussion of the questionnaire results, while chapter six describes the results from the interviews. Finally, chapter seven concludes this study by summarising the findings of the previous chapters and by offering recommendations for lecturing staff and making suggestions for further research.

CHAPTER 2: LITERATURE REVIEW

2.1 Technology, teaching and learning

2.1.1 Blended teaching and learning

Although *blended learning* is generally seen as learning through a combination of face-to-face instruction and online learning, a wide variety of (sometimes contradicting) definitions of the term can be found. Where the term 'blended learning' should ideally focus on learning from the student's perspective, and 'blended teaching' on the pedagogy and teaching methods, these terms are often used interchangeably. Oliver and Trigwell (2005) argue that definitions of blended learning often do not address students' learning, but rather focus on the methods of instruction, teaching or pedagogies. This suggests that the term 'blended teaching' would be more appropriate in a number of the definitions.

Driscoll (2002) identified the following four different concepts of blended learning:

1. A combination of web-based technology in order to reach a goal.
2. A combination of pedagogical approaches for optimal learning (irrespective of the use of technology).
3. A combination of any form of instructional technology with face-to-face instructor-led training.
4. A combination of technology with actual job tasks.

Some of the definitions of blended learning do not refer specifically to the use of technology or online learning, although it is not excluded by the definition. Heinze and Proctor (2004) and Kerres and De Witt (2003) interpret the term blended learning as a mix of didactical methods and delivery formats.

> Blended learning is the effective combination of different modes of delivery, models of teaching and styles of learning (Heinze & Procter, 2004, p. 2).

Kim (2007) defines blended learning as a combination of some form of traditional learning and some form of e-learning. According to Watson (2009) blended learning "combines online delivery of educational content with the best features of classroom interaction and live instruction to personalise learning, allow thoughtful reflection, and differentiate instruction from student-to-student across a diverse group of learners" (p. 4).

Vignare (2007) also describes blended learning as the integration of "online with face-to-face instruction in a planned, pedagogically valuable manner" (p.38). Wallace and Young (2010) warn that the combination of online and face-to-face instruction must be pedagogically sound and that blended learning must be more than a mere "add-on" to a course.

Teachers' perceptions of blended teaching also vary considerably. In a study by Ellis, Steed and Applebee (2006) at two Australian universities, four categories of perceptions of blended teaching were identified. Firstly, teachers see blended teaching as a way of assisting students to develop and apply new concepts as made possible by technology, in alignment with the learning outcomes. The second category regards blended teaching as a means of developing understanding by aligning media and technology with the intended outcomes, but emphasises both face-to-face and online activities. The third category that emerged sees blended teaching as a way of providing students with ways of accessing information, for example putting up lecture notes on an internet site. Little or no mention was made of integrating that information with learning outcomes. The final category views blended teaching as reducing the responsibility of the teacher. It emphasises the role of technology at the cost of teacher-student relationships and learning outcomes, by "filling the gaps" in their face-to-face instruction when out of the classroom.

For the purpose of this study, the following definition of blended teaching will be adopted, an adaption of the definition of blended learning of Alvarez (2005):

> *Blended teaching is a combination of traditional face-to-face teaching with various technologies, utilising the advantages of both these components to create an optimum programme.*

Reasons for implementing blended teaching and learning vary. Some teachers' purpose could simply be the introduction of technology to the student in order to offer support to weaker students or to reduce the face-to-face component (Kaczynski, Wood, & Harding, 2008). Graham (2006) says that the most common reason for using blended learning provided found in literature is that blended learning combines the best of both practices, but warns that if not designed effectively, the blended learning environment can also combine the least effective elements of both worlds. According to Wallace and Young (2010) there are three main reasons for moving towards a practice of blended teaching and learning: firstly, to make learning more accessible and flexible for students, secondly, to improve teaching practices and learning outcomes, and lastly to improve use of available resources. Graham, Allen and Ure (2003) agrees with this, citing improved pedagogy, increased access and flexibility, and increased cost effectiveness as reasons why people implement blended learning.

Blended learning has many benefits. It promotes moving away from the traditional passive transfer of knowledge by the teacher, towards a more learner-centred approach (Padayachee, 2010). According to Padayachee it accommodates learners with different learning styles, allowing them to learn at their own pace in their own way.

In 2005, Bonk, Kim and Zeng predicted ten trends that are linked to blended learning. We summarise four of these predictions:

Mobile blended learning: Blended learning will increasingly involve handheld devices, especially cell phones. Technology such as this might possibly make learning more easily accessible for a wider range of individuals.

Self-determined blended learning: As the options for blended learning increase, individual needs will be increasingly addressed. The learner will take more responsibility for the amount of blending of his or her programme, as well as the forms of blending. The learner will need to self-regulate his or her own learning because of increased use of exploratory and self-paced learning.

Increased connectedness, community, and collaboration: Increased connectedness, collaboration, and global awareness will be promoted by blended learning. It brings people, activities, and events together creating online communities and learning practices where knowledge, ideas and practices can be exchanged, expanding the need for shared knowledge, communities of practice, and collaborative learning.

Increased authenticity and on-demand learning: Real world scenarios and cases are likely to increase genuineness, encouraging the trend toward online case-learning, scenario learning, simulations and role play, and problem-based learning.

2.1.2 Technology and learning

Bransford, Brown, and Cocking (2000) state that the use of computer technology in learning environments has increased dramatically over the last four decades, and will continue to do so in years to come. According to them

> …new technologies provide opportunities for creating learning environments that extend the possibilities of "old"—but still useful—technologies—books; blackboards; and linear, one-way communication media, such as radio and television shows—as well as offering new possibilities (p. 206).

These authors argue that new technologies should not just be seen as a source of information, but as a powerful pedagogical tool. It opens up opportunities to enhance curricula by bringing into the classroom problems to be explored and solved, which are based on real-world problems. It can be used as a tool to scaffold learning and give opportunities for more feedback, serious thought and contemplation, and revision. Technology is ideal for building global learning communities that include people from different backgrounds, including teachers and practicing scientists.

Building global learning communities and the predicted trends in blended learning as summarised above can be linked to the idea of personal learning networks (PLNs) and personal learning environments (PLEs).

According to Warlick (2009) the idea of a PLN is not new:

> We have long relied on our families, friends, colleagues, and acquaintances to supplement our knowledge about the world. Our professional learning also comes from reference books, the textbooks we carried home from college, the television and radio stations we tune in to, and the professional and personal-interest periodicals to which we subscribe. And we have been connecting with people and information through the digital realm for decades (p. 13).

He claims that developments in information and communication technologies have given people access to new sources of information (Facebook, Twitter, Google Docs, YouTube, Skype, Google Reader, Second Life, Mailing Lists, Diigo, Ning, Delicious, Google Talk, wikis, and blogs), allowing them to expand their personal learning networks, empowering them to transform their learning experiences according to their needs. Not only students, but educators as well should use these new technologies to grow their own PLNs (Warlick, 2009).

PLEs are based on the idea that learning is self-directed, a continual process that takes place in different contexts and cannot be provided for by a single provider (Attwell, 2007). Warlick (2009) defines a PLE as a set of tools needed to support this learning and says that PLEs aim to include all forms of learning, including informal and formal learning. Wilson (2008) defines these tools as

> … the technologies with which an individual engages in learning, either on an individual, self-directed fashion or as a participant in a wider network. Personal tools are the extensions of their user; they offer a means with which to engage with the network of services, people and resources that constitute the PLE (pp. 20-21).

New technology, such as instant messaging, social networking, file sharing and blogging, provides new possibilities for learning (Attwell, 2007) through "interaction, collaboration and conversation" (Taraghi, Ebner, Till, & Mühlburger, 2009, p. 1).

In spite of its tremendous potential, the presence of technology in classrooms does not automatically enhance teaching and learning – it can even impede learning if not used appropriately (Bransford, Brown, & Cocking, 2000). Using technology effectively depends on the way teachers integrate the technology into their teaching. Educators use technology for various purposes, such as record-keeping, creating study guides, lesson plans, assignments and tests, and communication with students and parents. Inside the classroom, the use of technology includes presenting purposes, exploration by students, or for drill and practice purposes (Judson, 2006).

According to Bitner and Bitner (2002), the stimulus for the use of technology in education should be to enhance learning. The integration of technology shifts the traditional point of view of the teacher providing knowledge and the student absorbing it, to students discovering knowledge themselves, solving problems and communicating with others. Also, it is necessary to cultivate a climate that allows people to fail without loss of self-respect. A certain amount of failure is to be expected when using computers. These mistakes should be seen as lessons learnt.

2.1.3 Technology and teaching

Hooper and Rieber (1999) identified five phases in the use of technology for teaching:

1. Familiarisation – exposure to technology on the most basic level.

2. Utilisation – focus is on finding ways to use new technology.
3. Integration – focus shifts from learning technology to effectively using it in teaching.
4. Reorientation – redesign teaching strategies, focusing on goals of instruction.
5. Evolution – the teacher is able to cope with change and adapt to new technologies.

According to Hooper and Rieber (1999) teachers are unfortunately often satisfied with limited use of technology and do not pass beyond the utilisation phase. They show little commitment to it, and as soon as problems appear, they abandon it. According to Loch (2005), teachers often use new technology in the same way as the older technologies, and not to its full potential, due to user's lack of knowledge and comfort of familiarity.

Several factors that affect successful integration of technology into teaching have been identified:

- Lack of technology (hardware and software) affords little opportunity for teachers to integrate technology (Bauer & Kenton, 2005; Hew & Brush, 2007).
- Access to technology, even if technology is available, is not guaranteed (Hew & Brush, 2007). This may be the result of scheduling problems (Bauer & Kenton, 2005).
- Basic computer skills of teachers – developing skills for personal use of computers can help teachers to become more familiar with computers and the internet (Bauer & Kenton, 2005; Bitner & Bitner, 2002; Hew & Brush, 2007).
- Fear of change and fear of technology – the integration of technology into teaching causes even more fear since it changes teaching pedagogies and incorporates technologies often unfamiliar to the teacher. Overcoming these fears is crucial to successful implementation. Since change often is painful, teachers must be motivated to brave the process of change. Sometimes extrinsic motivation needs to be provided (Bitner & Bitner, 2002, Judson, 2006). In a reflection Buteau (Buteau & Muller, 2006) writes:

    > I am currently in my second year as faculty in the Department and I'm coming from a rather traditional mathematics education. I knew that I was joining a department that makes extensive use of technologies in its courses. Therefore I had mixed feelings, anxiety, insecurity and excitement (p. 7).

- Lack of technology-supported pedagogical knowledge – many teachers find integrating computers into their teaching difficult as they have little or no pedagogical knowledge of the use of technology (Hew & Brush, 2007). It is necessary to provide models that use technology in the classroom for teachers. They also need to be aware of different programmes that can be used, and be able to evaluate these programmes (Bitner & Bitner, 2002).
- Time constraints – it may take hours to prepare lessons and activities involving computer technology (Hew & Brush, 2007). Making time in the curriculum to incorporate technology is also often a problem (Bauer & Kenton, 2005).
- Availability of technological support – onsite, on-going support also needs to be provided. If technical problems are experienced, they need to be able to get support fast! (Bitner & Bitner, 2002).
- The beliefs and attitudes towards technology held by teachers will affect the way that technology is used. If, for example, a teacher believes that the use of computers does not lead to faster learning or better understanding, the teacher will not include computers as an integral part of his/her teaching (Hew & Brush, 2007) .
- Subject culture – teachers are often not prepared to integrate technology that is not in line with their subject culture, or shaped by the subject content, pedagogy and assessment (Hennessy, Ruthven, & Brindley, 2005; Hew & Brush, 2007).

Hannan and Silver (2000) name a number of institutional factors that will encourage innovation in teaching and learning:

- support from the person in authority;
- equality between research and teaching is established and reflected by institutional policy;
- interest in spreading the outcomes of innovation is shown by people in authority;
- resources are made available through the department or innovations fund.

Conversely, according to Hannan and Silver (2000) innovation may be obstructed when:

- teaching and learning are regarded in lower value, compared to research;
- there is a lack of recognition by colleagues and people in authority;
- individual, alternative initiatives are precluded by policies;
- difficult procedures exist for approval, support and resources;

- risk taking is impeded by quality assessment procedures.

Hannan (2005) found that new learning technologies may be introduced in large institutions where research is regarded as more important than teaching – in order to free staff from the burden in terms of time to teach while maintaining the quality of the course. In institutions where teaching and learning are of higher priority, according to Hannan (2005), innovations resulting in rewards for those involved may be supported, intendi ng to enhancing the reputation of a course, department or institution. He further claims that innovation is unlikely to be a rewarding experience unless institutions make efforts to enhance the learning of their students a high priority.

2.2 Mathematics and teaching technologies

Teaching mathematics with technology has not been accepted widely. According to Galligan, Loch, McDonald, and Taylor (2010) a lecturing mode that requires the teacher to write solutions on a board, is still widely used for teaching mathematics at both universities and schools. Lectures are traditionally given by writing on a white/chalkboard, or on transparencies on an overhead projector.

According to Buteau and Muller (2006) "evolution and innovation in university mathematics education is a slow process" (p. 1).

One reason for this, they claim, is that technological innovations implemented in a course by an individual faculty member (lecturer), seldom survive when that course is taken over by another lecturer. To affect lasting change, they say that faculty members in a mathematics department must reach a consensus and should work as a team to redesign its mathematical programmes.

2.2.1 Chalkboards

Writing on slate for educational purposes can be dated as far back as the 11th century in India, and the use of chalkboard/blackboards and chalk became widespread in the early 19th century (Wikipedia. Blackboard). According to Friedland, Knipping, Rojas and Tapia (2004) the major advantage of the chalkboard is that it slows down the lecturer, as everything must be written down in class and diagrams must be drawn, especially in subjects such as mathematics, chemistry, physics and other sciences, where slide-based lectures are not widely used. They argue that

> … teaching with a chalkboard is like thinking aloud, making clear for the students all the different steps involved in a proof or in the construction of a diagram (p. 17).

Anderson, Anderson, McDowell and Simon (2005) also address the advantage, often stressed by chalkboard style instructors, of writing the material at a pace that is comprehensible for students, both for listening and for note-taking.

Even now, although new technologies are available, it seems as though chalkboards (blackboards) are still popular and preferred by many instructors, according to anecdotal evidence found on the internet. Replies to the question "Why do most math professors prefer giving lectures using chalkboards rather than whiteboards or projectors?" posted on Quora (2014), included the following:

Nathan Pflueger, (Assistant professor in mathematics at Harvard) said

> … in math, the hard part isn't learning the facts, but learning the process. A blackboard or whiteboard is very effective at showing the process in real time … Mathematicians generally prefer substance to gimmicks. You see this in many aspects of the culture. I do admit that this noble impulse does sometimes go too far towards stodginess.

Klara Sjo, (grammar teacher) replied

> …writing on a board, be it black or white, gives you an opportunity to show a process; in many subjects the road from A to B is the important (and interesting), and vital for understanding. I guess this is [the] reason for mathematicians still loving the blackboard.

Chris Buddle (2012), (McGill University, USA) in his blog article "In praise of chalk: the value of teaching without technology" even goes so far as to encourage instructors to start teaching with chalk again. The reasons he gives include pacing the lecture, attempting not to cover too much material in one lecture, as well as quick changes and corrections.

> … write, erase, write, erase: the chalkboard allows for quick and efficient "changes" to a sentence, graph, or mathematical equation. You can change on the fly, and quickly adjust what you write, and fix mistakes (Buddle, 2012).

He also claims that teaching with a chalkboard requires a lecturer to be well-prepared and know the content.

> … no faking it: it is very, very difficult to give a lecture on a chalkboard if you don't know the material. You cannot depend on the PowerPoint slide to guide you, instead you actually have to prepare carefully. No excuses. Technology can be a crutch and allow an instructor to appear as if they know the content (Buddle, 2012).

The following is a summary of reasons given by instructors for preferring to teach by using the chalkboard, compiled from *anecdotal* evidence found on the internet:

1. Writing on the chalkboard reflects thought processes.
2. It slows down the pace of the lecture, so that students have more time to (process) understand the content.
3. Students need to take notes in class, engaging with the content.
4. Slideshows reduce the opportunity for student-generated content or concerns.
5. The instructor must be well prepared and have the subject matter well under control.
6. It takes less time to prepare a lecture for the chalkboard than preparing a slideshow.
7. It is easy to fix mistakes.
8. Students (and lecturers) spot mistakes made while writing on the chalkboard more easily than picking up mistakes on slides.
9. It helps you to keep track of the big picture. It is often possible to have the whole lecture on the chalkboard at once, while only one slide is displayed at a time with projectors.
10. The classroom is lit brightly – when using electronic technology the lights are often dimmed and students easily fall asleep.
11. It is easier to erase than whiteboard markers, to start with a "clean slate".
12. Chalk is cheap.
13. Chalkboards are low maintenance and it keeps on working – where whiteboard markers and electronic technology sometimes fail.

2.2.2 Electronic boards

The chalkboard (and dry whiteboard) inspired the development of technologies such as electronic blackboards and interactive whiteboards (IWB).

> The E-Chalk architecture is based on the metaphor of the classical chalkboard, enhanced by intelligent assistants running in the background (Friedland, Knipping, Rojas, & Tapia, 2004, p. 16).

An interactive whiteboard is a large, touch-sensitive board, it controls a computer connected to a digital projector. Electronic boards offer many of the advantages of using chalkboards, together with the advantages of modern technology, such as saving, printing or sharing the material written on the board (Greiffenhagen, 2002).

Despite the development of these technologies, some lecturers remain unconvinced, as is proved by the following remarks:

Klara Sjo (Quora, 2014):

> Recently we've changed from blackboards to smart boards, which is a mixed experience. It has many of the same advantages as blackboards … and I like that I can save the pages. The writing experience is not the same though, writing on a blackboard is way better …

Chris Buddle (2012):

> A smart board allows for a nice interplay between static and dynamic delivery of content. There are also tablets and apps that can really act like a smart board … I would argue, however, that even these tools are not the same as the spontaneity and engagement that is possible with the good old chalkboard. It’s not surprising that classrooms across the nation still install chalkboards: economical, efficient, engaging.

2.2.3 Non-interactive presentations

Although non-interactive computer technologies, such as PowerPoint presentations which use prepared slides, are widely used in modern lectures, Loch and Donovan (2006) question the effectiveness of these technologies for the teaching of mathematics. Although slides can be prepared for mathematics, it is time consuming and solutions prepared beforehand allow little flexibility in class (Galligan, Loch, McDonald, & Taylor, 2010). Where an interactive learning approach is used, the lecturer develops a solution from scratch and students can contribute to a particular path, but this aspect is lost when everything is prepared before the lecture begins (Loch, 2005). This limits the flexibility of the presentation which often results in passive learning, as the presentation cannot be adjusted according to students’ reactions. Problems and their solutions should be delivered in real time (Loch & Donovan, 2006) as students

> …need to be shown step by step how to work out a problem, and how to write down a solution in a clear and precise, mathematically correct way. Students need to learn mathematical explanation (Loch, 2005, p. 231).

In their research on the use of iPad technology in a statistics course, Manuguerra and Petocz (2011) claim that even (non-interactive) slides designed to be interesting are not sufficient to engage students. Lecturers then need to digress from slides to the whiteboard, allowing students to see "how things are built from the ground up" (p. 62). They found that although student feedback on this approach is usually positive, students often lack adequate note-taking skills, and some of the benefits of this approach are lost.

In anecdotal evidence found in Quora (2014), David Joyce, professor of mathematics at Clark University, stated that

> … PowerPoint doesn't work for math very well. You can't put much on a slide, and if you try, you might as well be projecting a book or printed notes. Math is a written language, and if you want to say anything impromptu, you'll have to abandon PowerPoint and write what you want to say.

2.2.4 Tablet PCs

A tablet PC is a notebook (laptop/portable computer) with a touch screen (the capability of using the screen for input) and is usually furnished with a stylus for writing on the screen. This attribute of the tablet PC, together with its handwriting recognition software, makes it a valuable tool for teaching. The lecturer uses the stylus and tablet PC, connected to a projector, instead of transparencies and/or chalkboards. Freehand notes can be created (e.g. in Windows Journal), or existing files can be annotated (e.g. Word files or PowerPoints). Mathematical software can also be used on the tablet PC. PDF documents can be converted for making annotations.

Olivier (2005) used lecturing software, namely Classroom Presenter, on a tablet PC which allows annotations to prepared slides. He believes this is a good tool for teaching mathematics and lists several advantages of using the tablet PC with this software:

- There is improved class interaction due to eye-contact which allows greater responsiveness from the lecturer.
- Mathematics ICT (Information and Communications Technology) leads to improved quality of prepared slides.

- Filling in of planned gaps after some discussions with handwritten annotations using high quality inking tools allows for better communication.
- Proofs and problem solving can be made more visible by using the multi-coloured pen and highlighter functions.
- If necessary, earlier work can be easily revisited.
- The ability to save the handwritten annotations is useful to discuss aspects of the lecture with students afterwards and to make the lecture notes available to students electronically.

Apart from the Classroom Presenter, other software for use on a tabletPC has been developed specifically aimed at teaching, such as the Tablet Myler Slides Classroom Presentation system and Inkseine. Golub (2004) describes the advantages of Tablet Myler Slides Classroom Presentation system over traditional Mylar slides (transparencies) in its use for teaching a discrete mathematics course. InkSeine was developed for use on tabletPCs that supports note taking, "coupling a pen-and-ink interface with an *in situ* search facility that flows directly from a user's ink notes" (Hinckley, Zhao, Sarin, Baudisch, Cutrell, Shilman, Tan & Desney, 2007, p. 251).

Tablet PCs have been widely used in mathematics and science teaching since 2004 at Murray State University in an effort to renew the traditional lecture (Fister & McCarthy, 2008). They describe some of the advantages of using the tablet PC:

- Using different colours and highlighting; this can enhance notes made by the lecturer.
- Creating a document including the lesson outline, allowing the lecturer to fill in details as the class progress.
- Saving and making available these class notes on the internet afterwards.
- When using Math Journal, software that includes handwriting recognition software, equations can be solved and algebraic manipulations carried out. However, Fister and McCarthy (2008) report that the software sometimes has trouble to distinguish between some symbols when using the character recognition capability.

According to Fister and McCarthy (2008), the ability to save class notes, and making them available to students on the internet, has had the most significant impact. This allows students, who learn more effectively when they focus their attention on the lecture, to do just that. The result of assessments given to classes that used tablet PCs, show a 10–15%

improvement over the control group (traditional classroom). Student evaluations were also positive and the majority of students downloaded the lecturer's notes at some point. Students, in general, agreed with statements that the tablet PC increased the lecturer's teaching effectiveness and that it promoted student learning. (Fister & McCarthy, 2008).

Anderson et al. (2005) on the other hand warn that when using new technology in the classroom, there is a risk that "the technology becomes a distraction rather than a complement" (p. T2G-18). Looking at the computer screen instead of the audience when using a tablet PC can be a temptation, however, one often sees lecturers addressing the chalkboard or PowerPoints slides, so this problem is not unique to tablet PCs. (Anderson, Anderson, McDowell, & Simon, 2005).

Some of the disadvantages of using the tablet PC and Classroom Presenter system given by Olivier (2005) include the fact that preparing high quality slides in Classroom Presenter is time-consuming, the technological learning curve for prospective presenters is steep, and tablet PCs are expensive.

Tablet PCs, with the use of additional software such as BB Flashback, has the ability to make a synchronised recording of audio (lecturer's voice) and the tablet PC screen (slides, annotations and notes made during the live lecture). This recording can be made available to students via the LMS or internet. Bonnington, Oates, Parnell, Paterson, and Stratton (2007) claim that this type of recorded lecture has a relatively small file size compared to video files of lectures captured on video camera, which tend to be large and therefore not practical to be downloaded by students over the internet.

Galligan et al. (2010) argue that although the tablet PC can be used to write step by step solutions to problems in class, incorporating suggestions by students, once it has been written, the solution becomes static, like solutions in textbooks. Using the recording capabilities of a tablet PC allows the solution and lecturer's explanations to be captured as they are writing it and these recordings are made available to students via the LMS. In their study, according to Galligan et al., this practice did not cause class attendance to decrease.

However, Yoon and Sneddon (2011), who investigated two undergraduate mathematics courses at a New Zealand university that used recorded lectures, found that this feature decreased students' class attendance. The excellent likeness of these recordings to the live lectures gave students the chance to experience the same learning opportunities outside as in the classroom. The most detrimental effect was on students that did not attend the live lectures, intending to watch the recorded lecture but failed to do so – the availability of the recorded lectures gave them a false sense of security. They argue that

> …many of the benefits and dangers associated with the use of recorded lectures lie more in the degree to which students can control their use of the technology, rather than any inherently good or bad feature of the technology itself. (p. 442 – 443)

Yoon and Sneddon (2011) hypothesise that a high level of student interaction in the live lectures would result in the recordings being used as a supplementary rather than the primary resource. Viewing the recorded lecture after attending the live lecture, gives students a chance to revise some of the concepts they did not understand during the live lecture, at their own pace, by pausing the recording in order to think of ideas and examples. Some students also used the recordings to revise for exams, although this appears to have no correlation with students' grades. In general, watching lectures (live or recorded) is a limited way to learn as students need to become involved in solving mathematical problems themselves in order to deepen their understanding and proficiency. They advise that some lectures should be replaced by small group tutorials.

Tablet PC technology can also be used in an interactive tablet PC based classroom, as described by Romney (2009). In large classes, where students work individually on problem-solving exercises during class, it is not possible for instructors to see their students' work. Tablet PCs, where students write on the screen, seems to be a solution as they can make handwritten notes in an electronic form. The lecturer can distribute PowerPoint slides (electronically), so the need for students to focus on note taking is reduced as students just annotate the slides electronically on their tablet PCs. If the tablet PCs are connected by a network, students can also transmit their solutions to the lecturer and display this for peer-critiquing, so they can learn from mistakes and approaches used by their peers (Romney, 2009).

2.2.5 Tablet technologies

Like tablet PCs, mobile tablet technologies such as the Apple iPad and Samsung Galaxy tablets can also be used with good results for teaching. Tablets can be connected to a data projector directly with a cable, or with wireless technology (for example using AirServer to connect the iPad via Wi-Fi to a laptop PC, which is connected to a data projector). Manuguerra and Petocz (2011) describe their experiences using the iPad for various purposes in teaching at a university that offers courses to both internal (face-to-face) and external (distance) students. Advantages of using the Apple iPad as described by them include the following:

- Lecture presentations can be lively and spontaneous, as slides can be annotated in real time.
- All notes, graphs and formulae written during the lecture can be recorded on the iPad.
- Increased student interest and participation results, and students feel safer because they can access details later.
- Lectures can be recorded by capturing visuals (screen) as well as audio. These videos can be made available to external students for learning purposes and to internal students for reviewing.
- Lecturers can use the iPad to communicate with and instruct external students, for example by making visual and audio recordings of explanations instead of static explanations.
- Students can submit assignments in electronic format (PDF) and lecturers can open and grade them on the iPad, annotating the assignment and including audio comments, in applications that allow for this.

As can be seen, these advantages are similar to the advantages of the tablet PC.

Tablets can also be used interactively in classes. Audi and Gouia-Zarrad (2013) relate such an experiment where iPads were used for teaching an introductory mathematics course for 17 engineering students. The teaching environment was paperless, and a set of applications was installed on each student's iPad to support delivering course content, class quizzes, text book materials and real time communication with students. Students connected to a wireless network. A research study was conducted to analyse the benefits of the iPad and Audi and Gouia-Zarrad (2013) describe in their preliminary findings that the integration had a positive impact on average students. They also found that instructor-student interaction increased, making the class more dynamic, and that student concentration improved. They plan a more in depth evaluation of the use of the interactive tablets conducted over a course length to "confirm that this positive result will not fade once the initial excitement dissipates" (Audi & Gouia-Zarrad, 2013, p. 54)

2.2.6 Problems experienced with tablet technologies

Loch and Donovan (2006) describe mixed experiences after implementing tablet technologies. Their results suggest that the "lecturer's competency and dexterity with the tablet is a key factor in the successful teaching with this tool" as benefits of tablet technology can be outweighed by technical issues. In a linear algebra course taught with an A3 size graphics tablet, students responded negatively to the technology – the lecturer found the graphics tablet difficult to handle and carry, and encountered a number of technical difficulties with the software which wasted valuable teaching time. Students also found her handwriting on the tablet difficult to read.

Anderson et al. (2005) also address some critical factors for clarity when using systems such as Classroom Presenter on a tablet PC, namely legible handwriting, attention to pen colour and contrast with background, cluttering of slides and displaying the slides long enough for students to comprehend the material.

2.2.7 Use of technology in undergraduate mathematics

Technology offers opportunities for assessment. Engelbrecht and Harding (2004) suggest the use of online assessment as a complement to standard paper-assessment, as these two types of assessment have different objectives. They claim that online assessments, consisting of both Provided Response Questions (PRQ) such as Multiple Choice Questions (MCQ), and Constructed Response Questions (CRQ), can be used as valuable diagnostic and formative tools, and can be used especially to test students' core knowledge, but also to test lower and higher level cognitive skills. Regular quizzes provide rapid feedback and

> …students soon get to use it as a formative tool and as a fair judge of their progress (p. 222),

but online assessment with MCQs and CRQs can also be used as a summative tool by combining it with a standard paper section with CRQs in semester tests and exams. Where online assessment usually does not allow for partial credit, grading of the paper section does. Angus and Watson (2009) also found that student learning can be enhanced by regular testing with online methods as

> …the formative aspects of this kind of assessment (eg, the opportunity for multiple attempts, immediate feedback, randomised questions and numbers) are arguably only attainable in the online format (p. 270).

Cazes, Gueudet, Hersant and Vandebrouck (2006) studied a few cases where online resources, named e-exercise bases (EBB), were used to teach and learn mathematics at three universities in France. In addition to exercises, these resources included hints, tools such as a graphing tool, and feedback (explanations, corrections and scores). These resources were mostly used in small tutor or training sessions, with a teacher or tutor present. Cazes et al. point out that although a student's answer may be correct, an EEB cannot truly analyse the student's procedure.

In a comparative study of certain undergraduate courses at two South African universities, Anguelov, Engelbrecht and Harding (2001) ask the question whether

> technology, as a mathematical tool, will have any application in a linearly organised axiom-theorem-proof course (p. 4).

They argue that a reason why computer technology has had little impact on curricula of undergraduate mathematics courses at South African universities could be because most of these courses have such a linear organisation. On the other hand, courses that focus on exploration and self-discovery can make immediate use of computer-based mathematical tools.

Integrating technology into undergraduate mathematics teaching is not simple. Pemberton and Cretchley (2001) conducted research at two universities on the integration of mathematical software packages, by focusing on the attitudes of students. These researchers suggest that differences identified between mathematics and computer based affective responses represent distinctive sets of characteristics with a permanent presence in computer-assisted mathematics learning:

> We believe that the commonalities and differences identified within our programs serve to highlight the complexity involved when powerful technology is introduced into undergraduate mathematics teaching. Much more is involved than trying to do faster and more cheaply that which was done formerly with blackboard, chalk, and paper (p. 255).

2.3 Conclusion

Although many definitions for the term ‘blended teaching’ can be found in literature, for the purpose of this study, the following definition of blended teaching is adopted:

> *Blended teaching is a combination of traditional face-to-face teaching with various technologies, utilising the advantages of both these components to create an optimum programme*

The above definition of blended teaching will be used to address the research question of this study.

CHAPTER 3: THEORETICAL FRAMEWORK

3.1 Introduction

Since the scope of this study does not include teaching pedagogies, but limits itself to exploring the use of different technologies by the staff lecturing undergraduate mathematics at the University of Pretoria's Department of Mathematics and Applied Mathematics, the theoretical framework does not include learning theories. For this study, it was necessary to develop a framework for classifying or measuring each lecturer according to their use of and attitude towards technology. As a basis for the development for this framework, two studies have been selected. The first study, by Engelbrecht and Harding (2005) describes their attempt to arrive at a way to measure the online components of undergraduate mathematics courses. In the second study, Oates (2004) recounts his attempt to measure the degree of technology use in tertiary mathematics courses.

3.2 Developing the framework

Different attempts to classify or measure the extent of the online component in blended or online mathematics courses have been made. Harmon and Jones (1999) identify five levels, based on the amount of internet use. The first level is where the instructor uses the internet mostly for communication of administrative information to students and little or no course content is available online, whereas on level five, all the course content is available online and interactions happen online.

In their attempt to arrive at a classification and means of measuring the online components of undergraduate mathematics courses, Engelbrecht and Harding (2005) focus on the different ways of using the internet, rather than only the amount of internet use.

They then make use of a radar chart with six radials axes. The scoring on each radar is obtained by rating the responses (0 - 5) to the question relating to the particular characteristic, given in Table 1.

Table 1 Engelbrecht and Harding's taxonomy for measuring the extent of online components in mathematics courses

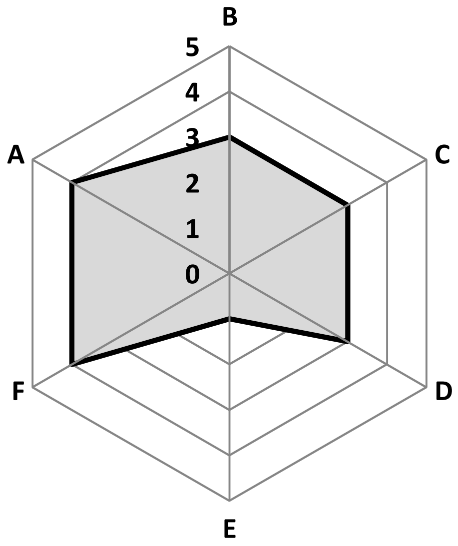
	Characteristic	Example of question asked to examine each characteristic
A.	Dynamics and Access:	What is the frequency of access expected for success in the course?
B.	Assessment:	How much of the assessment is done online?
C.	Communication:	How much of the communication happens online?
D.	Content:	How much of the course content is available online?
E.	Richness:	How many online enriching components does the course have?
F.	Independence:	How independent is success in the course from face-to-face contact?

By placing the radials Dynamics, Assessment and Communication, grouped under the heading "interaction", at the top, and the other three radials, Content, Richness and Independence, grouped under the heading "material" at the bottom, the shape of the radial chart can be used to categorise a course. A radial diagram that is top heavy indicates more interaction while diagrams of content courses will be heavier to the bottom.

Engelbrecht and Harding (2005) warn that the objectives of the course design do not necessarily include all the radials, so that although the area of the radial diagram does measure the extent of internet utilisation, a larger area does not necessarily mean a better course.

As an example, they categorised a course at the University of Pretoria. The course does not run fully online – it is presented for residential students and provides for one hour of contact (discussion session) per week, but has no formal lectures. A textbook is prescribed, and detailed study objectives, short lecture notes, and problems are provided daily. These activities are not monitored. Communication takes place via online discussion forums and e-mail. Online assessment, such as weekly quizzes, forms an important part of the assessment. Students also hand in four hard copy assignments, (which consist mainly of selected problems) and a group project that requires the use of mathematical software, during the semester.

Figure 1 Example of Engelbrecht and Harding's radar chart



The radial chart shown in Figure 1 is top heavy, and the diagram indicates that the online components of this course are more interactive but that it lacks richness. More multimedia material could supplement the course.

Oates (2004) identified and defined six characteristics that broadly describe the extent of the integration of specifically mathematics-enabling technology, such as CAS-calculators, graphics calculators and computer software in mathematics courses. He then also makes use of radar charts in order to measure and compare the level of integration of these technologies in different courses, for example two undergraduate calculus courses.

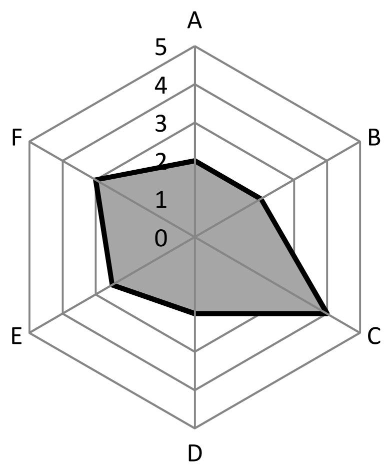
Table 2 Oates's taxonomy for measuring integration of technology into mathematics courses

	Characteristic	Example of question asked to examine each characteristic
A.	Access	To what extent do students have access, e.g. is it compulsory?
B	Student facility	How facile are students with the use of the technology, and what assistance is provided to help them?
C	Assessment	Is technology expected and/or permitted in assessment?

D	Pedagogy	How and when do the staff and students interact with the technology? For example, is it used mainly as a complex calculation device and demonstration tool, or to develop and explain concepts?
E	Curriculum	Has the course curriculum, for example content, order of teaching, changed to reflect the use of technology?
F	Staff facility	Are staff familiar with the use and capabilities of the technology?

According to Oates (2004) the shape of the shaded area in the radar charts characterise the level of technology integration in a course. On the right-hand side radials A, B, and C measure the ability of students to use the technology, while the left-hand side radials D, E and F measure the design and delivery of the course. The area of the shaded area is indicative of the extent to which technology has been integrated into the course.

Figure 2 Example of Oates's radar chart



In the example above (Figure 2) a value of 2 was assigned to the access component (radial A), since calculators in this course is optional, and only about 10-20% of students possess one. For assessment (radial C), the course receives a 3, since although the calculators are allowed in all assessments, the test and final exam attempt to be calculator-neutral.

3.3 A scale for measuring technological use by mathematics lecturers

The instruments developed by Engelbrecht and Harding (2005) and Oates (2004) were developed as instruments for categorising the online components of mathematics courses and for measuring the integration of specifically mathematics-enabling technology into undergraduate mathematics courses, respectively.

These instruments are however not suitable for the purpose of this study, since they focus on blended mathematics courses. The focus of this study is on the mathematics teaching staff themselves and the extent to which they use technology for blended teaching (although the nature of the mathematics courses taught by a lecturers may influence the extent of his or her use of technology).

For the purpose of this study a similar but new model needs to be developed. The following five areas of technological uses that will be measured in order to build a technological profile of each lecturer were identified:

A. Technology for use by teacher in the classroom as a teaching tool

This area focuses on the extent to which modern (electronic) technology is used in the classroom as a teaching tool. The use of computers with projectors, especially the use of tablet PCs and appropriate computer software is of particular interest in this key area.

B. Technology for use by the student as a learning tool

This area refers to the use of online tools or computer software packages that are incorporated into the curriculum by the lecturer, for use by students outside of formal lecture times.

C. Use of an LMS as an academic tool

The University of Pretoria makes use of an LMS, (Blackboard, called clickUP) that incorporates different tools that can be used for academic purposes, other than just for administration and communication. These include basic tools such as making available course content, e.g. class notes and video mash-ups, discussion boards, assessment tools such as tests and surveys and also a tool called Collaborate which has a white board function, allowing the lecturer to explain mathematics to students, synchronously online.

D. Use of an LMS as an administrative tool

The LMS used by the University has several tools intended for administration and communication purposes. These tools include announcements, calendars, email and Grade Center where grades received by students can be recorded and calculated.

E. Use of technology on a personal level.

It was decided to include this area into the instrument and technological profile, as an individual's general attitude, fears and beliefs towards technology can greatly influence his or her willingness to integrate technology into his or her teaching practices and pedagogical approach (Bitner & Bitner, 2002; Hew & Brush, 2007; Judson, 2006).

As demonstrated in Table 3, the instrument that was developed for measuring the use of technology by mathematics lecturers is based on the five uses identified above.

Table 3 Instrument for measuring use of technology by mathematics lecturers

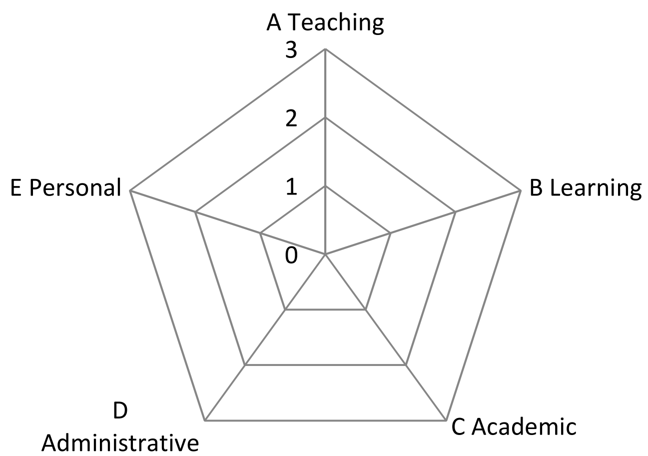
A	**Technology for use by the teacher in the classroom as a teaching tool**
0	Chalkboard only
1	Limited use of technology (e.g. overhead projector, microphone, overhead camera)
2	Use of technology e.g. computer or tablet PC and projector, less than 67%* of teaching time
3	Use of technology e.g. computer or Tablet PC and projector, 67%* or more of teaching time
B	**Technology for use by student as a learning tool**
0	None
1	Used in courses taught, but administered by someone else
2	Manage at least one online facility or software package
3	Manage two or more online facilities or software packages

C	**Use of LMS as an academic tool**
0	None
1	Limited used
2	Moderate use
3	Extensive use
D	**Use of LMS as an administrative tool**
0	None
1	Used in courses taught, but administered by someone else
2	Personally use one or two LMS administrative/communication features
3	Personally use three or more LMS administrative/communication features
E	**Use of technology on a personal level**
0	Do not keep up with advances in technology, do not use smartphone
1	Keep up with advances in technology at a basic level, use smartphone
2	Keep up with general advances in technology and use smartphone or tablet (e.g. iPad)
3	Keep up (strongly) with general advances in technology and use smartphone and tablet (e.g. iPad)
*	A percentage of 67% was decided upon, as in order to obtain a rating of 3 out of 3, a lecturer should be using modern technology at least two thirds of teaching time

3.3.1 Radar charts

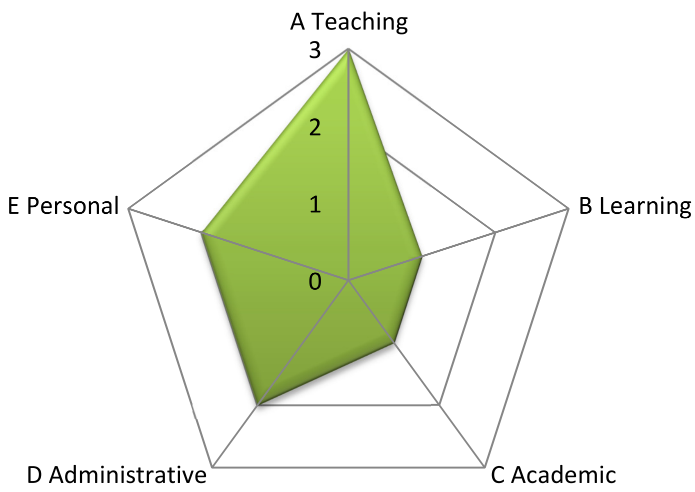
These criteria were used to measure the extent of technology use of each of the respondents and create a technological profile on a radar chart.

Figure 3 Radar chart to represent technological profiles of mathematics lecturers



The radar chart in Figure 4 shows the profile of a mathematics lecturer who uses technology quite extensively as a teaching tool in the classroom and moderately makes use of the LMS as an administrative or communication tool. However, the use of mathematical software online or otherwise to facilitate learning when not face-to-face, as well as the LMS as an academic tool to make content available or for assessment purposes, is limited.

Figure 4 Example of a technological profile on a radar chart



3.3.2 Rating of respondents

In order to make a statistical comparison of each participant's attitude and beliefs with respect to the use of technology for teaching mathematics versus their technological profile, it was decided to use a radial chart in order to rate the respondents on a scale. Initially the area was considered as a means to rate participants, as the area of the chart is indicative of the extent of the use of technology. However, this was decided against as the order of the radials could greatly influence this rating. Furthermore, the nature of the course taught would drastically influence the use of technology outside of the classroom; for example lecturers who teach axiom-theorem-proof courses, tend to make little or no use of technology.

A simple ranking system of summing the measures of the five different radials was therefore chosen, resulting in a scale ranking respondents on a scale of from 0 to 15. The respondent in Figure 4 would receive a rating of 9.

3.4 Measuring attitudes and beliefs

Participants' attitudes and beliefs with respect to the use of technology for mathematics teaching were measured by their responses to the following four statements, each rated on a Likert scale.

1. Even with modern technology available, I still believe the best way to teach Mathematics is the use of a blackboard and chalk/whiteboard.
2. Using an overhead projector and transparencies is a good way to teach Mathematics.
3. Mathematics is a discipline that lends itself to the use of technology for teaching.
4. Using technology adds value to my teaching.

The first two statements are directed at determining the attitude and beliefs of the teaching staff towards the use of traditional technologies, namely the chalkboard and overhead projector, for teaching mathematics. The last two statements aim to determine whether the teaching staff believe that mathematics lends itself to the use of technology for teaching and whether they believe that the use of technology adds value to their teaching, or not.

A value of zero to four was obtained from the responses to each of the statements and by adding these values a total score for each of the respondents resulted. These scores were used to rate participants were on a scale, with a minimum of 0 indicating the belief that technology is not suitable to teach mathematics at all, and a maximum of 16, indicating the belief that technology can be used successfully to teach mathematics.

3.5 Conclusion

In this chapter an instrument was developed to measure and rate respondents on their use of technology. A radar chart with five radials is used, namely

A Technology for use by the teacher in the classroom as a teaching tool

B Technology for use by student as a learning tool

C Use of LMS as an academic tool

D Use of LMS as an administrative tool

E Use of technology on a personal level

Respondents were rated on a scale from 0 to 3 on each radial and respondents get an overall rating for their use of technology by summing the scores on each of the five radials. The attitudes and beliefs of respondents with respect to the suitability of technology for mathematics teaching were also rated according to a collection of Likert items, and summing those values.

In chapter five, these two ratings will be used to compare the attitudes and beliefs of respondents against their age, gender and use of technology.

CHAPTER 4: RESEARCH DESIGN AND METHODOLOY

4.1 Introduction

The main purpose of this study was to determine the status quo of the use of a blended learning approach by the teaching staff of a mathematics department at a research intensive university in South Africa for teaching undergraduate mathematics. The Department of Mathematics and Applied Mathematics at the University of Pretoria (UP) was used as a case study. The secondary purpose was to address some of the attitudes, beliefs and perceived barriers that inhibit the implementation of technology.

In order to explore the blended approach followed by the lecturing staff at the Department of Mathematics and Applied Mathematics at UP, both inside the classroom and outside the classroom, the following research question was posed:

> **To what extent is a blended teaching approach currently used by lecturing staff for teaching mathematics at undergraduate level?**

The following sub-questions were posed in order to direct the exploration of the research question.

1. What are the attitudes and beliefs of the teaching staff with respect to the suitability of using technology for teaching mathematics?
2. What technologies do the teaching staff prefer to use? To what extent are these technologies used when lecturing undergraduate mathematics inside the classroom? How has this changed over the last ten years?
3. Do the teaching staff make use of the learning management system (LMS) as a tool for administration and communication purposes as well as for academic purposes? Do they use any other technologies as a tool for learning outside the classroom?

4.2 Research design

Since the aim of this study was to determine the status quo of the use of a blended learning approach by the teaching staff of the Department of Mathematics and Applied

Mathematics for teaching undergraduate mathematics at the University of Pretoria, it was decided to use a mixed methods approach. Firstly, a survey was done by using a pen and paper questionnaire. The questionnaire collected quantitative data as well as qualitative data.

In order to supplement the qualitative data, for a better in-depth understanding, semi-structured interviews were held with a selection of the respondents.

4.3 Methodology

4.3.1 The instruments

4.3.1.1 The questionnaire

A literature study of previous studies did not reveal any suitable (or adaptable) questionnaires, as many of the questionnaires found in the literature were focused on pre-service teacher training. These questionnaires were quite extensive and general, and did not ask appropriate questions.

A questionnaire to collect data was therefore developed by the researcher (APPENDIX B). The questionnaire was divided into four sections.

A. Demographical information

In this section, questions are asked in order to collect demographical data of the respondent, such as gender, age group, academic qualification, teaching qualification, years of teaching experience, and whether the respondent uses a smart phone or a mobile tablet.

B. Use of technology in the classroom

Questions in this section focus on the technologies used by the respondents inside the classroom for lecturing and teaching. The purpose is to collect data on the percentage of lecturing time spent per semester using different technologies, the reasons why lecturers choose to use the technologies they use, how they use it, and problems experienced with the technologies used.

C. Use of technology outside the classroom

Questions in this section focus on the technologies (software and systems) used by the respondents outside the classroom for academic purposes. The purpose is to collect data on the use of tools embedded within the LMS, as well as other software, e.g. MATLAB or other systems, e.g. WebAssign.

D. Attitudes towards technology

In this section respondents are mostly asked to respond to statements, in order to determine their attitudes and beliefs with respect to technology and the suitability of technology for teaching mathematics.

A decision was made to keep the questionnaire as short as possible to encourage the lecturing staff to complete the questionnaire in order to ensure a good return rate of questionnaires.

4.3.1.2 Interviews

Four participants were chosen for further interviews, based on their responses from the questionnaires. They were mainly chosen based on their use of technologies used in and outside formal lecture periods. The interviews were semi-structured, and lecturers were asked three leading questions:

1. What purpose does the chosen technology have?
2. How do the students react to these technologies?
3. What are the problems that you experienced with these technologies?

Sub-questions were also asked based on the interviewees' responses.

Finally, the interviewees were also asked to expand further on their use of tablet PCs or the chalkboard in order to obtain a deeper understanding of the motivation for their practices.

4.3.2 The participants

The population of this research study is staff members of the Department of Mathematics and Applied Mathematics who teach undergraduate mathematics courses at the University of Pretoria. Although most of the population of the study are staff members appointed on levels ranging from junior lecturer to extraordinary professor, two exceptions were made. One senior technical assistant and one assistant lecturer were included as participants in this study, as they both have had extensive teaching experience in mathematics courses at UP. Staff members who have no teaching duties or who only teach post graduate mathematics were also excluded. Although the questionnaire was handed out to all those staff members included in the study, and everybody was encouraged to participate, completion of the questionnaire was voluntary. A total of 48 questionnaires were distributed to staff teaching undergraduate mathematics in the Department of Mathematics and Applied Mathematics at the University of Pretoria and of these, 32 questionnaires were returned.

4.3.3 The researcher

At the time of the research study, the principal researcher was employed at the University of Pretoria in the Faculty of Engineering, Built Environment and Information Technology (EBIT) as a lecturer in an additional supportive mathematics course which formed part of the extended engineering degree programme (not as a lecturer in the Department of Mathematics and Applied Mathematics). The researcher personally has a strong interest in the effective use of technology for teaching mathematics, which may lead to researcher bias.

4.3.4 Data from the questionnaire

A total of 48 questionnaires were distributed to staff teaching undergraduate mathematics in the Department of Mathematics and Applied Mathematics at the University of Pretoria during February and March 2014. Of these, 32 questionnaires were returned, giving a response rate of 66.67%. Although the respondents were not required to identify themselves on the questionnaire, they were asked to indicate on a staff list if they returned the questionnaire. Analyses of the respondents were made with respect to gender, academic qualification, age group and post level.

Table 4 Analysis of return of questionnaires by gender

Gender	Number of questionnaires handed out	Number of questionnaires returned	Percentage
Male	33	21	63.6%
Female	15	11	73.3%
Total	48	32	66.7%

Table 5 Analysis of return of questionnaires by academic qualification

Academic qualification	Number of questionnaires handed out	Number of questionnaires returned	Percentage
Doctoral degree	32	18	56.3%
Masters' degree	13	11	84.6%
BSc Honours	2	2	100%
BSc	1	1	100%
Total	48	32	66.7%

Table 6 Analysis of return of questionnaires by age group

Age group	Number of questionnaires handed out	Number of questionnaires returned	Percentage
Under 35	6	4	66.7%
35-50	18	13	72.2%
50-65	17	11	64.7%
Above 65	7	3	42.9%
	48	31*	64.6%

* One participant did not indicate the return of her/his questionnaire

The age group of 65 and above is not well represented in the survey. These faculty members teach part time and were not all available during the period the questionnaires were completed. However, those who were unavailable to complete the questionnaire have a limited participation in teaching undergraduate mathematics.

Table 7 Analysis of return of questionnaires by position

Position	Number of questionnaires handed out	Number of questionnaires returned	Percentage
Professor	8	4	50%
Associate professor	5	3	60%
Senior Lecturer	10	7	70%
Lecturer	19	13	68.4%
Junior Lecturer	4	2	50%
Assistant Lecturer	1	1	100%
Senior technical assistant (teaching)	1	1	100%
	48	31*	64%

* One participant did not indicate the return of her/his questionnaire

The tables above show that in general the respondents are representative of the undergraduate teaching staff. Inferences made from the results could therefore be generalised to the undergraduate teaching staff of the Department of Mathematics and Applied Mathematics at the University of Pretoria.

4.3.5 Analysis

Both quantitative data and qualitative data were gathered in the questionnaire. Data were cleaned and inspected visually. A simple graphical analysis was used for descriptive data. Ordinal data were summarised in tables and represented in graphical format. Values were further assigned to the ordinal data in order to determine, compare and find a correlation between certain responses.

Responses to open-ended questions were read through and were grouped by themes and coded.

Audio recordings were made of the interviews and transcribed. As these interviews were conducted in the language (Afrikaans/English) in which the interviewee felt most comfortable with, and relevant parts of the interviews had to be translated into English. In such cases, quotations from the interviews are therefore verbatim translations of the interviewee's original words.

4.4 Ethical considerations

Ethical clearance was applied for and received by the Ethics Committee of the Faculty of Natural and Agricultural Sciences (APPENDIX A). Participation in this study was voluntary, although it was encouraged and supported by the department. The questionnaire did not require participants to identify themselves by name, except for those who indicated themselves willing to participate in further interviews. The participants were ensured that they would not be identified in the study.

4.5 Limitations

Although participants were encouraged to be honest in their replies, some of the responses relied on the memory of the participants, and it was not possible to verify this information. As this study is in the form of a case study, findings should not be generalised to other departments or universities.

4.6 Conclusion

The research methodology employed in the research was a case study with mixed methods to explore the blended approach followed by the lecturing staff at the Department of Mathematics and Applied Mathematics at UP, both inside the classroom and outside the classroom.

Participants in the study were the undergraduate mathematics teaching staff of the Department of Mathematics and Applied Mathematics, and 32 out of 48 participants responded to the questionnaire. Four interviews were conducted with participants.

Analysis of the data revealed certain themes and when compared with the literature review, interpretations and conclusions were arrived at.

CHAPTER 5: QUESTIONNAIRE RESULTS AND DISCUSSION

5.1 Introduction

Blended teaching is a combination of traditional face-to-face teaching with various technologies, utilizing the advantages of both these components to create an optimum programme.

Looking back at the definition accepted for blended learning in this study, whether to blend or not to blend within teaching and learning is no longer the question to be asked. Instead, blended teaching can be seen on a spectrum where on the one end only traditional face-to-face teaching occurs, and on the other end, all learning occurs by means of technology, with no face-to-face component. The introduction of learning management systems (LMS) such as Blackboard, at universities, has opened the doors for lecturers to move away from the one end of the spectrum, towards an optimum programme. At a very basic level lecturers can start to blend their teaching by using the communication tools of the LMS to communicate information about the course to the students.

The amount of blending that lecturers apply, could depend on various aspects – from the nature of the course taught and the availability of technology, to the attitudes, beliefs, knowledge, and skills of the lecturer with respect to technology.

5.2 Attitudes and beliefs

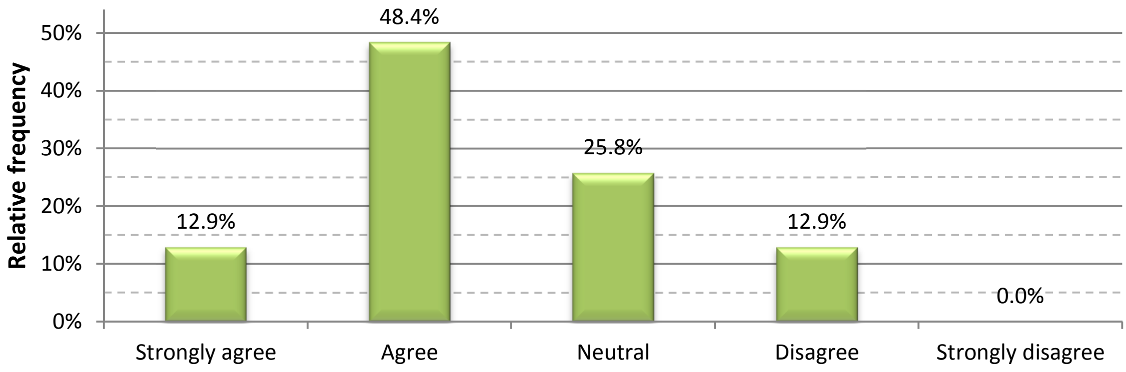
5.2.1 Introduction

As seen from the literature review, the attitudes and beliefs of the teachers towards technology, and the use of technology for teaching, play an important role in the implementation of technology. In order to determine these attitudes and beliefs with respect to teaching mathematics, undergraduate mathematics teaching staff at the University of Pretoria were asked whether they agree or disagree with a number of statements.

5.2.2 Results and discussion

In order to determine respondents' perception of their own awareness of advances in technology, respondents were asked to respond to the statement "*I keep up with general advances in technology*".

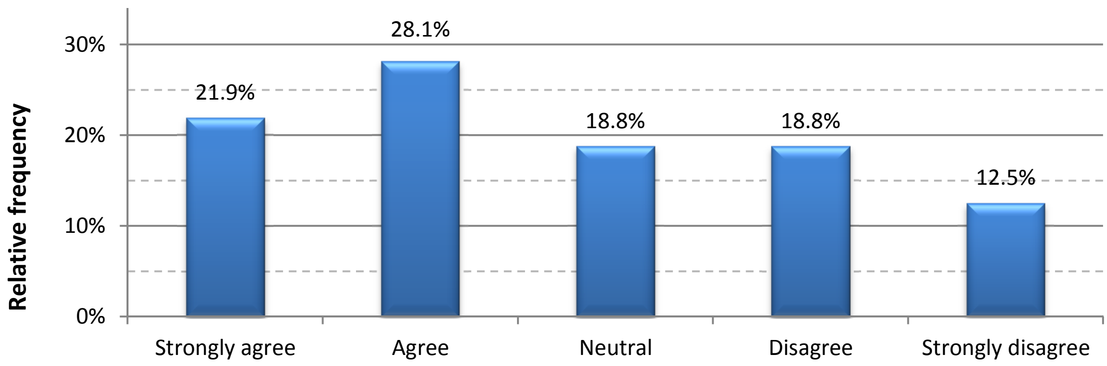
Figure 5 I keep up with general advances in technology



61.3% of the respondents agree with this statement, while only four of the 31 respondents (12.9 %) disagree with this statement, as shown in Figure 5. The four respondents who disagree are all males of 50 years or older. 70% of the female respondents (to this statement) agree. It seems that a majority of the respondents consider themselves "more or less up to date" with technological advances.

Participants were then asked to respond to the statement "*Even with modern technology available, I still believe that the best way to teach mathematics is the use of a blackboard and chalk/whiteboard*". Figure 6 shows the relative frequencies of the 32 responses to this statement.

Figure 6 Even with modern technology available, I still believe that the best way to teach mathematics is the use of a blackboard and chalk/whiteboard



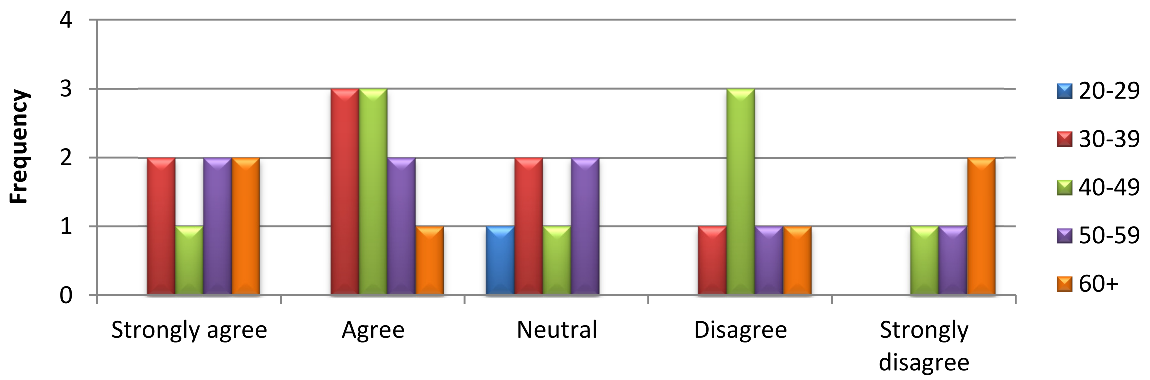
16 of the 32 respondents (50%) agree with this statement, while only 31.3% disagree with the statement. Six respondents (18.8%) remain neutral.

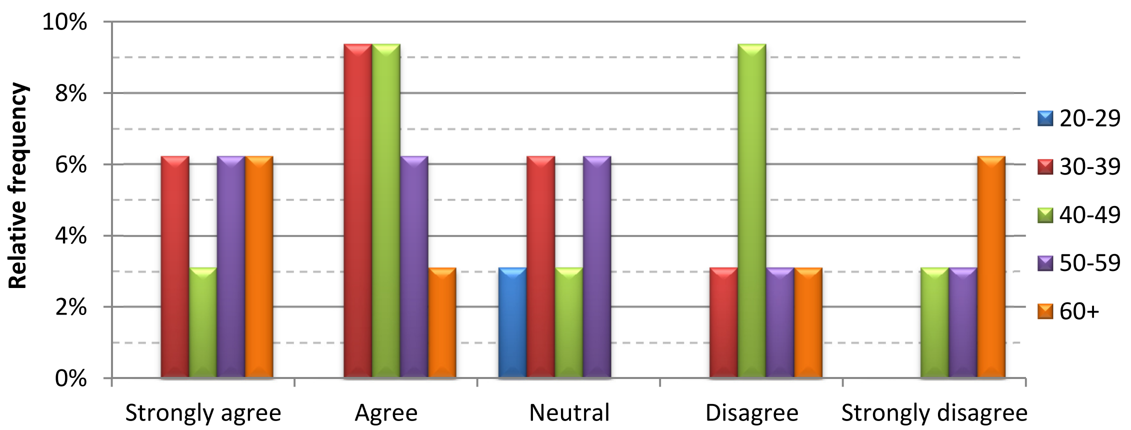
An assumption that could easily be made is that the teaching staff in the older age groups would be those who agree with this statement, while the respondents who disagree would be in the younger age groups. This assumption would be based on the idea that older individuals would be more set in their ways, while younger individuals are more likely to be open towards and adapt more easily to the use of technology. Table 8 shows the breakdown of the respondents by age and Figure 7 represents the breakdown of the responses to this statement according to their age groups.

Table 8 Breakdown of the respondents by age groups

20-29	30-39	40-49	50-59	60+
1	**8**	**9**	**8**	**6**

Figure 7 Even with modern technology available, I still believe that the best way to teach mathematics is the use of a blackboard and chalk/whiteboard - by age groups

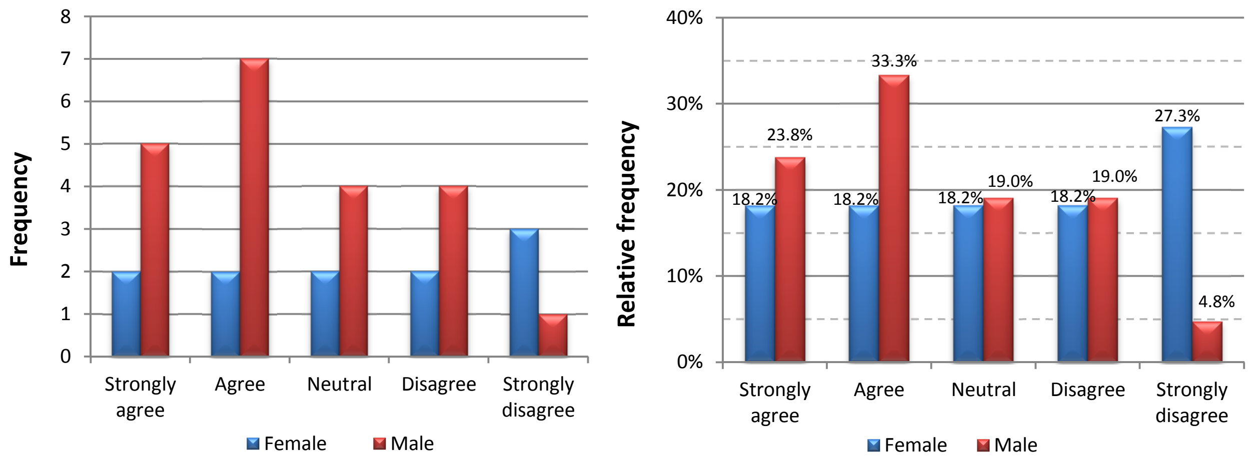




The results were unexpected. Not only is the correlation weak (0.12) between the age groups and agreement to this statement, but the only respondent under 30 is neutral, five of the eight respondents (62.5%) in the age group 30 to 39 agree with this statement and only one (12.5%) disagrees. Responses from those in the age groups 40 to 49 and 60 plus are symmetrically distributed with equal numbers of respondents in these age groups agreeing and disagreeing. Only one of the respondents who disagree with the statement is under the age of 40.

Figure 8 shows the breakdown of the responses to the statement with respect to gender.

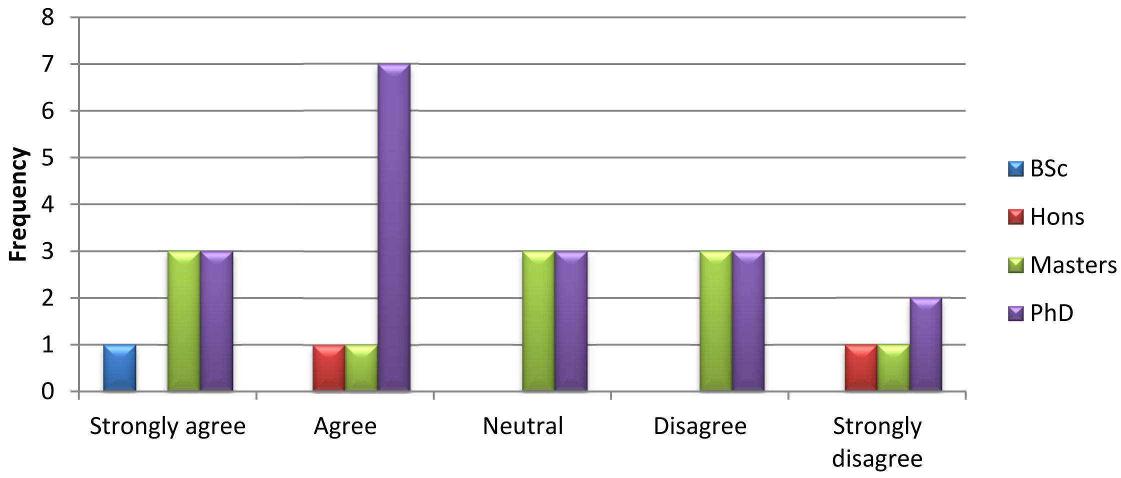
Figure 8 Even with modern technology available, I still believe that the best way to teach mathematics is the use of a blackboard and chalk/whiteboard - by gender



The results suggest that gender might be indicative in the responses to this statement as relatively more males (57.1%) than females (36.4%) agree with this statement, and relatively more females (45.5%) than males (23.8%) disagree with the statement. I will discuss possible explanations as to why this is the case in section 7.2.

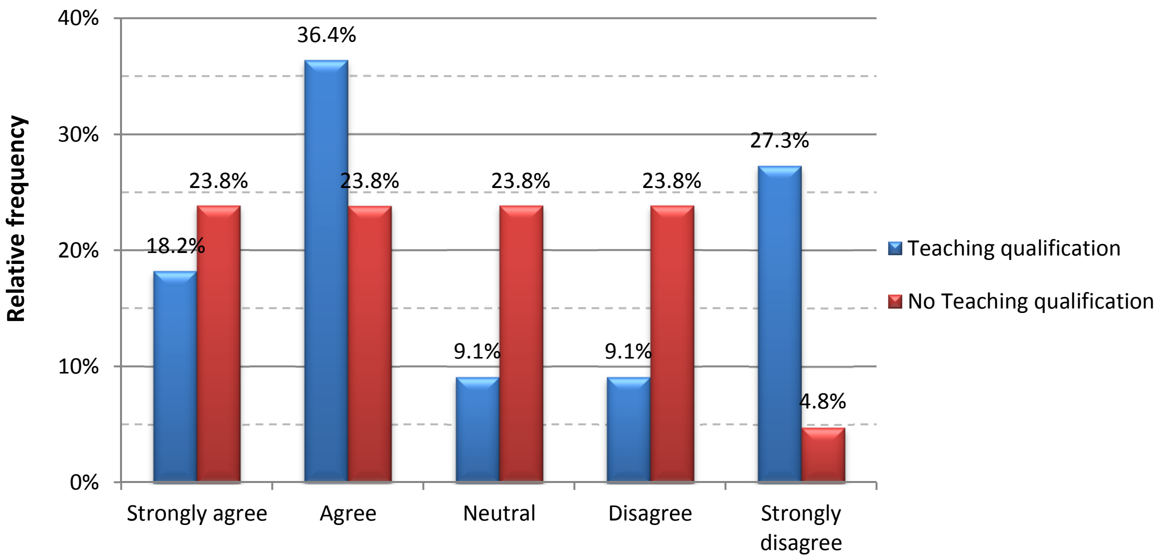
Figure 9 shows that ten of the 18 respondents (55.6%) holding a doctoral degree agree with the statement that the chalkboard is still the best way to teach mathematics, while only four of the 11 respondents (36.4%) holding a masters' degree agree with this statement. As the number of respondents holding a BSc or honours degree is so low, no deductions will be made from their responses.

Figure 9 Even with modern technology available, I still believe that the best way to teach mathematics is the use of a blackboard and chalk/whiteboard - by academic qualifications



In Figure 10 we see the breakdown of responses by teaching qualification.

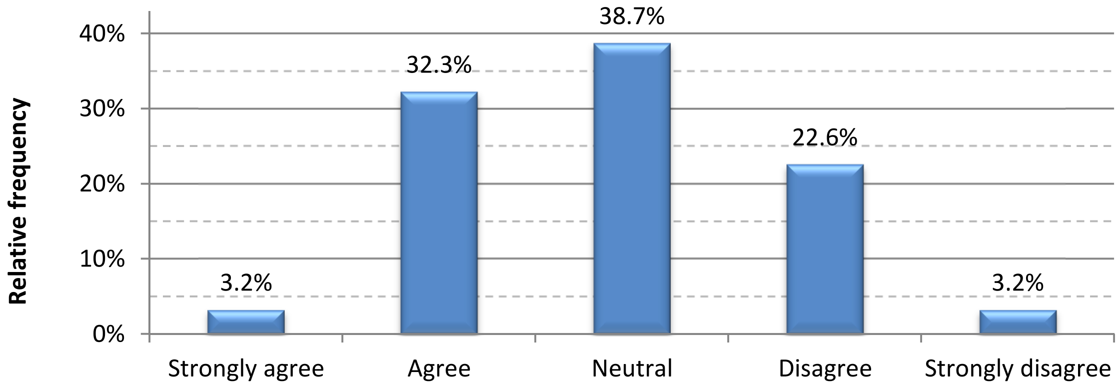
Figure 10 Even with modern technology available, I still believe that the best way to teach mathematics is the use of a blackboard and chalk/whiteboard - by teaching qualifications



Relatively more respondents holding a teaching qualification (54.6%) agree with the statement than disagree (36.4%) and similarly, relatively more respondents that do not hold a teaching qualification (47.66%) agree with the statement than disagree (28.6%).

Overhead projectors, together with transparencies, have long been used as an alternative for (or complement to) the use of chalkboards in education. Beliefs whether "*Using overhead projectors and transparencies is a good way to teach mathematics*" vary as seen in Figure 11.

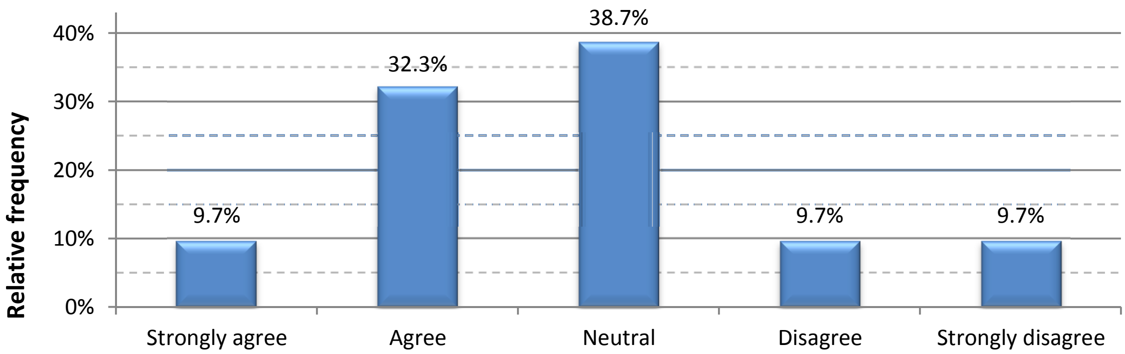
Figure 11 Using an overhead projector and transparencies is a good way to teach Mathematics



11 of 31 respondents (35.5%) agree with the statement while nine respondents (29%) disagree with this, although only two respondents have a strong opinion about this. The result is not completely unexpected. Responses to the statement "Even with modern technology available, I still believe that the best way to teach mathematics is the use of a blackboard and chalk/whiteboard" indicated a resistance to explore new technologies, so many would prefer to use an overhead projector instead.

Participants were asked to respond to the statement "*Mathematics is a discipline that lends itself to the use of technology for teaching*". Figure 12 shows the relative frequencies of the responses to this statement.

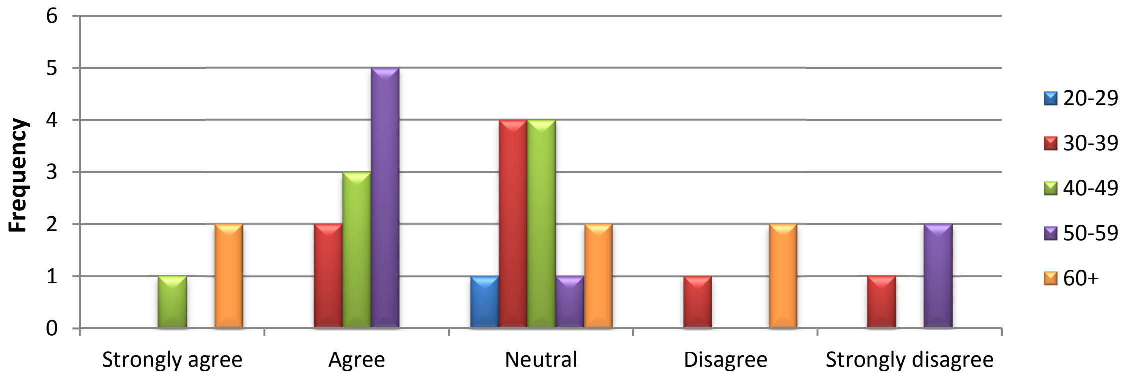
Figure 12 Mathematics is a discipline that lends itself to the use of technology for teaching

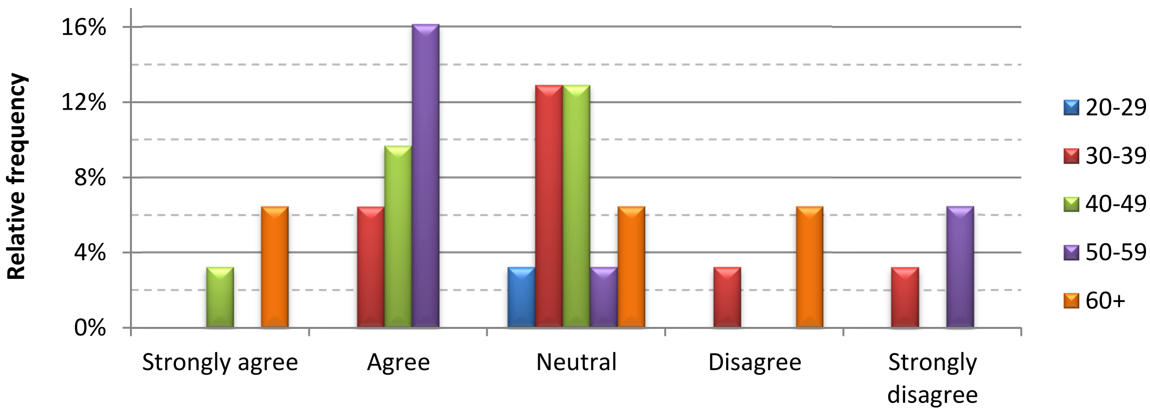


A total of 31 responses were received to this question, of which 13 respondents (41.9%) agree (10) or strongly agree (3) with the statement. Six respondents (19.4%) disagree (3) or strongly disagree (3) with the statement. More than double as many respondents were in agreement with the statement than not (13 compared to six) although a large percentage of the respondents (38.7%) remains neutral.

Figure 13 shows the breakdown of the responses with respect to age groups.

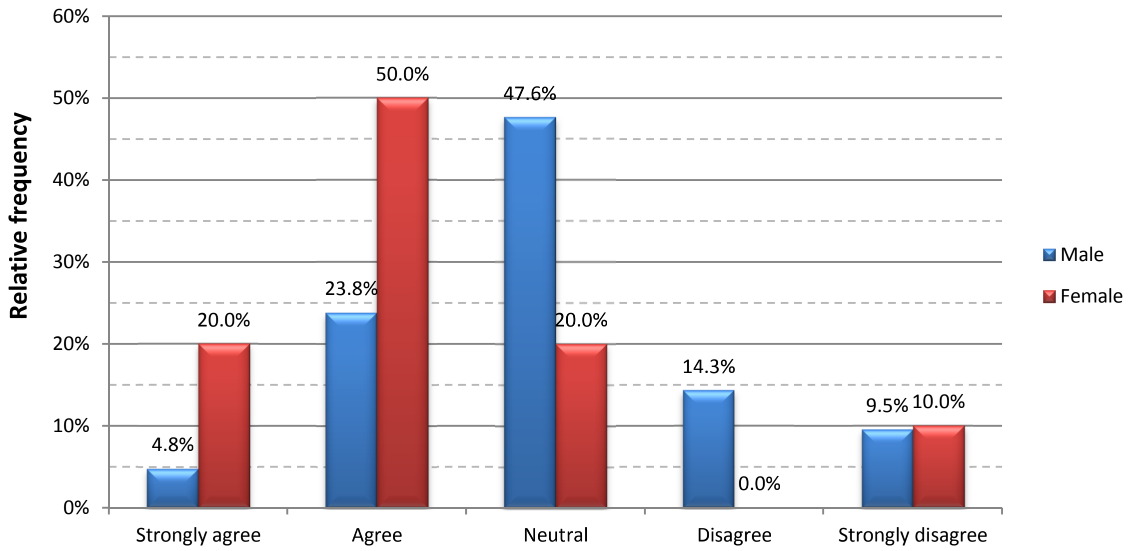
Figure 13 Mathematics is a discipline that lends itself to the use of technology for teaching – by age groups





Again, we see that the age of the respondents does not play a significant role (correlation of – 0.098), although it is interesting to note that only two of the 13 respondents who agree with the statement are under 40 years of age. Prensky (2001) describes the generation born after 1985 and growing up surrounded by digital technology, as *digital natives*, and those born before 1985 are referred to as *digital immigrants*. With the exception of one, the respondents fall into the latter category, and while some of them have "immigrated" into the digital world, others have not. The age of the respondents does not seem to play a role here.

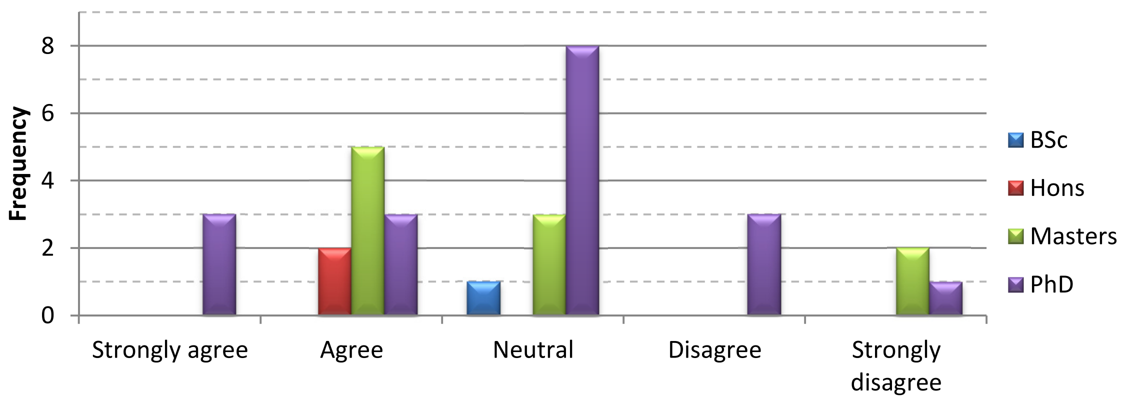
Figure 14 Relative frequencies - Mathematics is a discipline that lends itself to the use of technology for teaching - by gender



Again, gender appears to be an indication of whether respondents agree or disagree with this statement. Of the 21 male respondents, six (21.57%) agreed with this statement, five (23.8%) disagreed and ten (47.6%) remained neutral. Of the ten female respondents to this question, seven (70%) agreed, one (10%) disagreed and two remained neutral. Looking at the relative frequencies of these responses in Figure 14, it is clear that relatively more female respondents agree with the statement that mathematics is a discipline that lends itself to the use of technology for teaching, than their male counterparts.

Breaking down responses to this statement by academic qualification, does not reveal strong trends, whether agreeing or disagreeing with the statement, as seen in Figure 15.

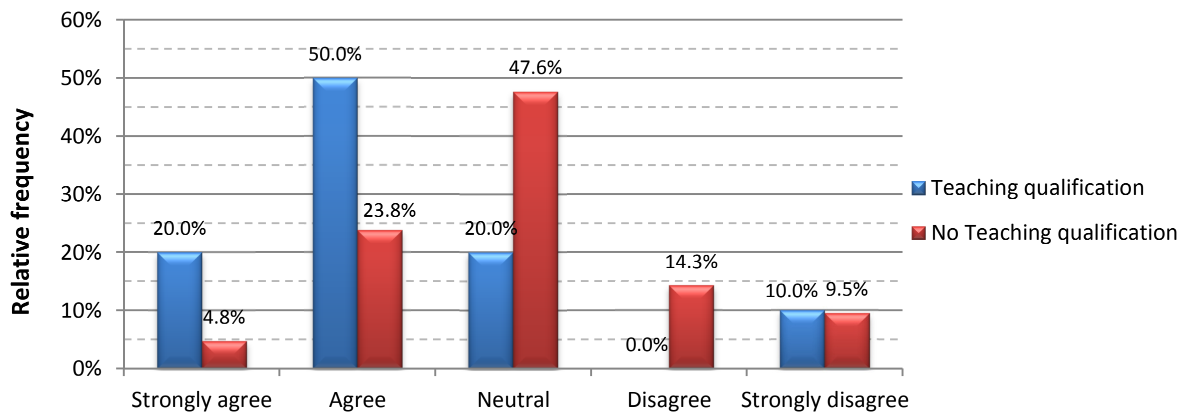
Figure 15 Mathematics is a discipline that lends itself to the use of technology for teaching - academic qualification



It is interesting to see though that all the respondents who strongly agree with this statement, hold a doctoral degree.

In addition to their subject academic qualifications, ten of the 32 respondents (31.25%) hold a teaching qualification. A breakdown of responses to the question is shown in Figure 16.

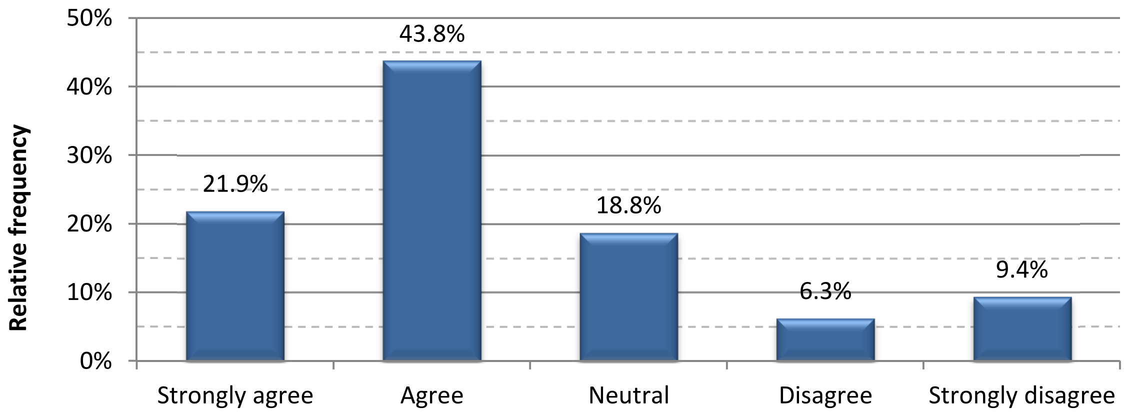
Figure 16 Mathematics is a discipline that lends itself to the use of technology for teaching - by teaching qualification



It can be seen that overwhelmingly more (70%) of the respondents with teaching qualifications agreed with this statement than disagreed (10%), compared to those without a teaching qualification of whom six (28.6%) agreed and five (23.8%) disagreed.

A breakdown of responses to the statement "*Using technology adds value to my teaching*" is shown in Figure 17.

Figure 17 Using technology adds value to my teaching

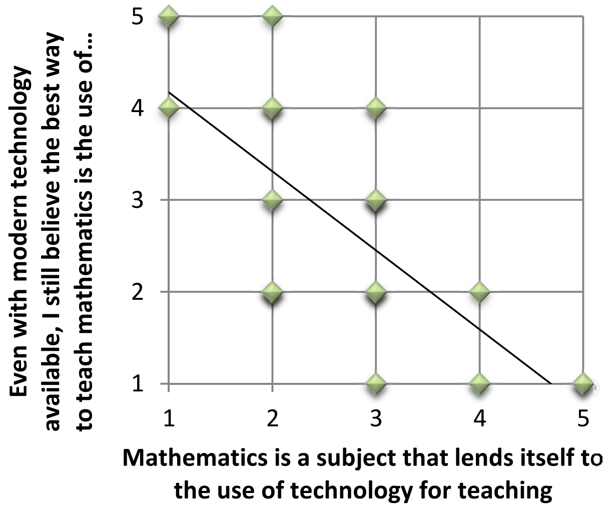


Where only 41.9% of the respondents agree with the statement that mathematics is a discipline that lends itself to the use of technology for teaching and 50% of the respondents consider a chalkboard/whiteboard as more suitable for teaching, 67.7% of respondents agree with the statement "Using technology adds value to my teaching". This inconsistency can possibly be declared by the way the respondents understood the concept "teaching" – simply as teaching within the classroom, or whether it also includes the use of technology outside the classroom.

Lecturers should however be aware that the use of technology does not necessarily enhance teaching and learning, if not used appropriately, as discussed in the literature review (Anderson, et al., 2005; Loch, 2005; Bransford, et al., 2000).

A comparison between the responses to the two statements "Mathematics is a discipline that lends itself to the use of technology for teaching" and the statement that "Even with modern technology available, I still believe that the best way to teach mathematics is the use of a blackboard and chalk/whiteboard", is shown in Figure 18. On both axes, strongly agree is indicated by 1, while strongly disagree is indicated by 5.

Figure 18 Blackboard and chalk/whiteboard still best VS Mathematics is a discipline that lends itself to the use of technology for teaching



Mathematics is a discipline that lends itself to the use of technology for teaching

Even with modern technology available, I still believe the best way to teach mathematics is the use of a blackboard and chalk/whiteboard

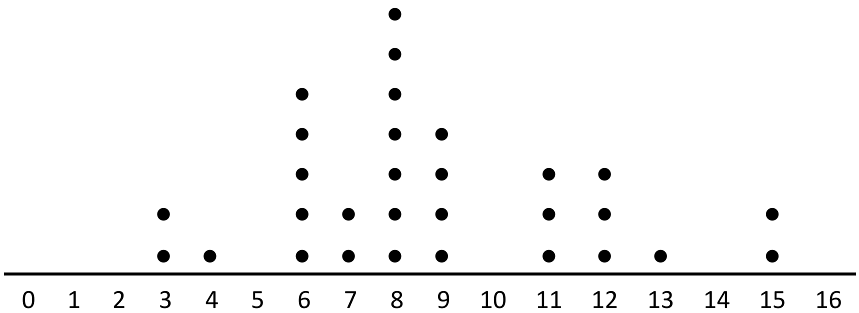
	SA	A	N	D	SD
SD	2	1			
D	1	3	2		
N		2	4		
A		4	4	1	
SA			2	2	3

As expected, there is a strong negative correlation (-0.72) between respondents' belief that chalkboards are still the best way to teach mathematics, and the belief that mathematics lends itself to the use of technology for teaching. All the respondents who strongly agree that mathematics lends itself to be taught using technology, disagree or strongly disagree with the statement that a chalkboard/whiteboard is still the best way to teach mathematics. Also those who disagree or strongly disagree that mathematics lends itself to be taught using technology, agree or strongly agree that a chalkboard/whiteboard is still the best way to teach mathematics.

The four respondents agreeing with both statements are of interest. One of the four occasionally uses a computer in class, while the other three make use of tablet PCs. These three all mention visibility in large classrooms as the reason why teach with technology – they are "forced" to teach in a way they would not necessarily have preferred.

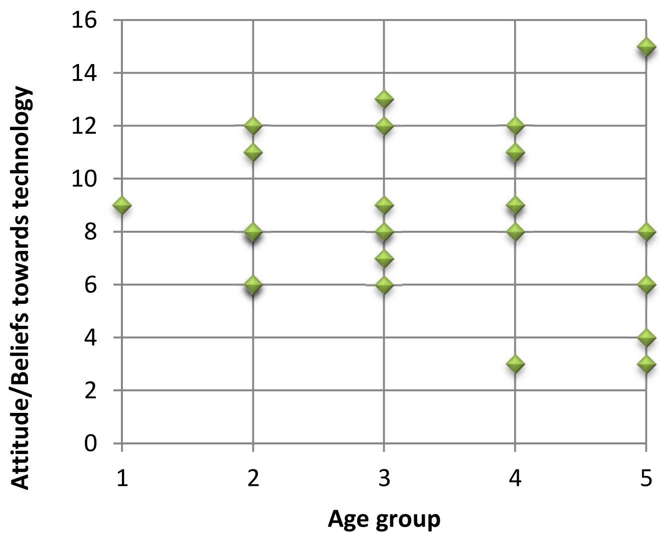
Using the scale from 0 to 16 as described in section 3.4, the attitudes and beliefs of 30 of the respondents were rated. The remaining two respondents were not rated due to incomplete responses. The mean score was 8.6 and the modal rating was 8 (with a frequency of seven), indicating in general a neutral attitude with respect to technology in mathematics. This is not surprising as all four statements received a large number of neutral responses. 13 respondents received a rating above 8, the highest two ratings being 15. Ten respondents rated below 8, with the two lowest ratings of 3. The ratings of all the respondents are shown in Figure 19.

Figure 19 Ratings of respondents' attitude and beliefs



It is interesting that the two respondents who received a rating of 15 each, are both in the age category of 60 years and older, but one of the two respondents receiving the lowest rating, is also in this age category. Figure 20 shows no correlation between the age group and the ratings of the respondents suggesting that the attitudes and beliefs are not significantly influenced by age.

Figure 20 Rating of respondents' attitude/beliefs towards the use of technology for teaching mathematics VS Age groups



Age group

1	20-29
2	30-39
3	40-49
4	50-59
5	60 and over

Nine of the ten respondents with a rating below 8 are male. Of the thirteen respondents who were rated above 8, six are male and seven are female. Again, gender does appear to influence the attitudes and beliefs of respondents in this study.

5.2.3 Conclusion

This section focused on factors that may influence the attitude and beliefs of the respondents with respect to technology and mathematics teaching. It showed that age and academic qualification do not seem to play a significant role in the belief that technology is suitable for teaching mathematics, although gender and holding a teaching qualification may influence this belief.

The belief that even with new technologies available, the chalkboard is still the best way to teach mathematics, suggests a strong subject culture in mathematics, as described by Hennessy et al. (2005) and Hew and Brush (2007). Other reasons could also exist why respondents prefer to use chalkboards for teaching, such as lack of computer skills, fear of change and fear of technology, lack of technology-supported pedagogical knowledge and lack of knowledge of available technologies (hardware and software). Section 5.3 will explore these reasons in more detail, while focusing on the technology used during lecture classes.

What is important, though, is that the beliefs and attitudes about technology held by teachers and lecturers will affect the way that technology is used (Hew & Brush, 2007). As long as they do not believe that the use of technology can enhance their mathematics teaching, one can assume that they will not increase their blended teaching.

5.3 Use of technology in the classroom during lectures

5.3.1 Introduction

The University of Pretoria is rated by QS Top Universities (2013) as an extra-large university with, as most South African Universities, a weak score for faculty-to-student ratio. As a result, lecture class sizes are often large, and classes of 200 or more students are common in first year mathematics courses. Face-to-face sessions for undergraduate mathematics courses at the University of Pretoria usually consist of a number of lecture periods per week depending on the credit load of the course, as well as a tutorial session, the length of which also depends on the credit load. For example, a first year calculus course for engineering students would consist of 4 lectures of 50 minutes each, as well as a tutorial session of approximately three hours per week, bearing 16 credits.

Lecture classes are usually lecturer-driven. Tutorial sessions comprise of smaller student numbers, and are generally conducted as pen and paper sessions, with the exception of a few modules. A course in pre-calculus (presented during the first semester to first year students in the extended degree programme and for education students) uses a computer lab during tutorials and mathematical software (CAMI Maths) focused on practicing mathematical skills. In a mathematics modelling course, students use MATLAB during their tutorial sessions to represent models developed in their lecture periods.

5.3.2 How the picture has changed between 2003 and 2013

By 2003 data projectors had not yet been installed in all the lecturing halls at the University of Pretoria, and furthermore, technology that allowed for interactive teaching (such as tablet PCs and interactive boards), was costly and not widely available.

As new technologies were developed and the cost of these technologies becomes lower, the use of modern, digital, interactive technology for teaching mathematics has become more feasible over the last decade.

In order to determine the change in their use of teaching technologies over a ten year period, participants were asked to indicate approximately what percentage of teaching time during a semester they spent using the different types of technologies in 2013, as compared to 2003.

One respondent indicated s/he had less than ten years' teaching experience, and did not complete the question on her/his use of technology in 2003. 29 participants responded to the question on their use of technology in 2003. Of these, only one person stated that s/he used an overhead projector more often than the chalkboard in 2003, while two respondents indicated equal use between overhead projectors and chalkboard. The other 26 respondents indicated that they mostly used the chalkboard. Only two respondents indicated that they used computers in their classes at all, and only for approximately 20% of the time.

By 2013 most of the lecturing halls at the University of Pretoria had been equipped with data projectors, making the use of computers, tablet PCs and other electronic devices such as iPads for teaching in classrooms possible. The Department of Mathematics and Applied Mathematics also adopted a policy of acquiring tablet PCs for use by teaching staff who applied for this, and as funds became available. At the end of 2013 the department had acquired 18 tablet PC's.

By 2013, the use of technology by teaching staff in the Department of Mathematics and Applied Mathematics at the University of Pretoria had changed significantly, as can be seen by comparing Figure 21 and Figure 22.

Figure 21 Use of technology – 2003

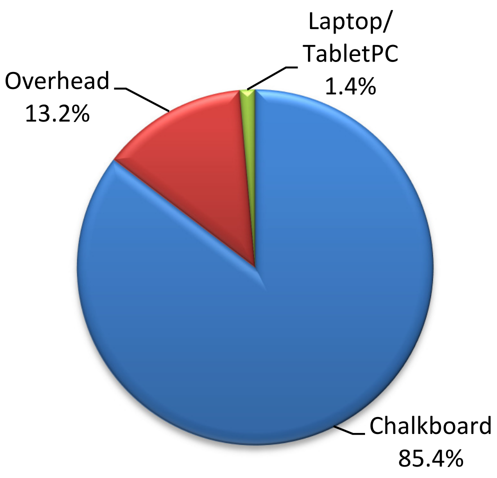
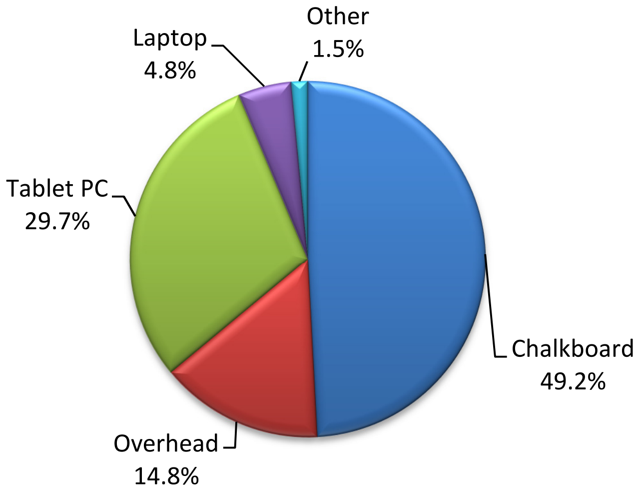


Figure 22 Use of technology – 2013



It is apparent from Figure 21 and Figure 22 that, according to the respondents, use of the chalkboard has decreased dramatically from 85.4% to 49.2%. Large classes, together with the availability of newer interactive technologies, can possibly explain this as the use of tablet PCs and data projectors have increased to 29.7% of the teaching time. The use of overhead projectors remains basically the same – from 13.2% in 2003 to 14.8% in 2013. However, it is not necessarily the same respondents who still use these. Some of those that used overhead projectors in 2003 have now adopted tablet PCs, while some of those who only (mostly) used the chalkboard in 2003, have since started using the overhead projectors.

Respondents were asked why they use modern technology or why they do not use modern technology in their lectures and various reasons were given by both groups – those who use modern technology, and those who still prefer using the chalkboard.

5.3.3 Chalkboards

In section 5.2.2 responses to the statement "Even with modern technology available, I still believe that the best way to teach mathematics is the use of a blackboard and chalk/whiteboard" was discussed. It was significant that 50% of the 32 respondents agreed with this statement. We also saw in Figure 22 that chalkboards/whiteboards are still used approximately 49.2% of teaching time. Whiteboards are generally installed only in computer laboratories where chalkboards are not allowed, and therefore not used during lectures.

Various reasons were given by the respondents why they do *not* use technology, or why they prefer the use of a chalkboard. These reasons were compared to the list in the literature review (section 2.2.1) summarizing the reasons why lecturers prefer to use a chalkboard for teaching (compiled from mostly anecdotal evidence found on the internet).

The following is a summary of the reasons given by the respondents:

- Better communication of mathematical ideas (point 1 on list)
- Better pacing of the lecture (point 2 on list):

> Provided the chalkboard is legible and well organized, Chalk & Talk is the most effective means of communicating subtle math ideas & it's at the right pace. Students often make this point themselves (Respondent 01).

- Student-lecturer interaction and the opportunity for student-generated responses and concerns (point 4):

> There is considerable anecdotal evidence that audiences absorb material more poorly when it is presented via PowerPoint or similar devices (Witness the now-common phrase "Death by PowerPoint" in schools.) This is important, especially in the context of Mathematics teaching, and needs to be better understood (Respondent 01).

> … better student-lecturer interaction when writing action is visible. Slides destroy student-lecturer interaction (Respondent 23).

- Time constraints: time that it takes to master new technology and time that it takes to prepare for lectures (point 6 on list):

> Large investment of time required to become confident user of modern technology (Respondent 07).

It takes too much time to prepare a lecture using modern technology. Blackboards work well for doing mathematics (Respondent 08).

- Mistakes are spotted more easily on the chalkboard (point 8 on list):

Students see the errors you make faster since they see the lines being written on board. Slides do not do this (Respondent 23).

- Having multiple chalkboards on which important theory can remain visible (point 9 on list):

In a good venue, with a class of moderate size, the area covered by the chalkboards is larger than the projection screen (Respondent 12).

Why not using a projector/tablet PC - you can't have more than one theorem on the board at a time (Respondent 24)

- Cost of technology (point 12 on list):

It is expensive (Respondent 08).

- Failure of technology (point 13 on list):

Modern technology [is] vulnerable to equipment failure, power outages, etc. (Respondent 08).

Can't rely on them [technology] (Respondent 20).

- Availability of technology:

I do not have access to other technology to make use of, but would prefer to use a tablet PC or computer when possible (Respondent 14).

What I do present works well enough. I don't have a tablet (Respondent 15).

At times a tablet PC would be useful, yet not all lecturers are provided with tablet PC's (Respondent 12)

- A strong belief that mathematics is not a subject that lends itself towards the use of technology for teaching:

The teaching of mathematics is an inherently low-tech activity. It can be supplemented by well-chosen high-tech interventions, but the basic process is fundamentally low-tech. There needs to be a distinction between technology that we might decide to use because we think it is effective, and technology that we consider bad but would be forced to use, because of aberrations in the

> teaching/learning environment, e.g. 300+ student in one room, chalkboard not clearly visible, etc. (Respondent 01).
>
> [Technology] gives illusion that solutions appear like magic (no effort) (Respondent 23).
>
> [Technology is] not too useful for math (Respondent 28)
>
> I am also reluctant to create a too strong association between mathematics and technology: it's all in the mind (Respondent 12).

- The nature of the mathematics course taught:

> I teach pure maths with proof - technology won't cement properly the arguments. Students say they do not feel the math (Respondent 30).

- Lack of training:

> Lack of training to those who never had technological interest before and suddenly it must be used (Respondent 18).

Some of the responses above suggest a perception (misconception) that using technology for teaching necessarily implies the use of non-interactive technology, such as prepared PowerPoint presentations as described by Galligan et al. (2010) and Loch (2005). Pacing of lectures, mistakes not spotted, no opportunity for student-generated responses and time required to prepare quality slides are all issues that relate to prepared slides and solutions, and do not take the properties of a tablet or tablet PC into consideration. As we shall see in the next section, tablet PCs at its most basic level can be used instead of a chalkboard, without any change in pedagogy or teaching style.

Further comparison of the reasons given above with the list of compiled in section 2.1.3 of the literature review, reveals the following factors that affect integration of technology into teaching: lack of technology, access to technology, time constraints, lack of technology-supported pedagogical knowledge and technological support, beliefs and attitudes towards technology, and subject culture.

5.3.4 Tablet PCs and data projectors

The first tablet PC used for lecturing purposes in the Department of Mathematics and Applied Mathematics at UP was acquired by a faculty member through her own research fund, and through her own initiative, in approximately 2003. Her enthusiasm about the advantages of the tablet PC, inspired a number of fellow faculty members to follow her example. Recently, the department adopted a policy to acquire tablet PCs for use by teaching staff that apply for this while funds are available, and a total of 18 tablet PCs had been acquired by the end of 2013.

It could clearly be seen from Figure 21 and Figure 22 that the use of tablet PCs and data projectors at UP for teaching undergraduate mathematics has increased significantly since 2003. Nine respondents who indicated that they use tablet PCs are female and four male respondents indicated the use of tablet PCs. Of the 13 respondents that use a tablet PC, eight indicated that they use it 90% or more of their teaching time. The practice of combining the use of tablet PCs with other technologies such as overhead projectors and cameras, and chalkboard in one class are widely used – only three respondents indicated that they use a tablet PC 100% of the time during a semester:

> Use a tablet [PC] for my lecture. Display e.g. pocket calculator on camera when necessary/graphs/sketches. Chalkboard – announcements (Respondent 11).

Only one lecturer indicated that he uses a computer (laptop, not a tablet PC) and data projector approximately 60% of the time in his classes, while also using Scientific Workplace, Excel or MATLAB.

Reasons for using tablet PC

Reasons why lecturers increasingly choose to use a tablet PC for teaching vary. Reasons concur with some of the advantages cited by Olivier (2005) or Fister and McCarthy (2008). The following is a summary of the reasons given by the respondents:

- Ability to prepare material before the class and annotating this on the tablet PC

> One can prepare certain material beforehand. More versatile in class. Clean. Always facing the class. Can adjust size of letters (Respondent 09).

> (I do my prep on the tablet. I copy sections (problems from the text book) and write on tablet.) This gives me time to interact with students while they are working on the problem (Respondent 21).

- Ability to save the notes made by the lecturer in class for future use, and uploading it on the LMS:

> I can give students electronic versions of my lectures (Respondent 13).

I get to share notes with students on clickUP [LMS] and have them on computer for future use (Respondent 16).

- Use of colour to make lecture notes more interesting:

More fun (can use colours) (Respondent 16).

- Feeling of empowerment and more control of their classes when using a tablet PC:

It's the way of the 21st century. It makes me bigger & better (Respondent 22).

It maintains discipline; they become more attentive; they can all see on the screen, each and everything written (Respondent 27).

It captures students' attention, opens new possibilities which enhance my lectures (Respondent 11).

I use it to teach more effectively and to manage classes better (Respondent 06).

- Visibility in large venue halls with a large number of students:

I use it because it allows students to see what I am doing; the venues do not lend themselves to chalk and talk anymore (Respondent 13).

The classes are large and there are no longer blackboards in all the venues (Respondent 04).

In a bigger venue visibility is important - are students able to follow you? (Respondent 10).

Blackboards and overhead projectors are not feasible for teaching large groups (Respondent 22).

Classes are larger - students can see better, there is more space (Respondent 31).

Visibility was indicated by the majority as a reason why they use a tablet PC. Of the 13 respondents that indicated they use tablet PCs, six cited visibility as the only reason for using tablet PC and projector, but three others also included this reason as motivation. The need to feel empowered and more in control increases as class size increases.

How the tablet PC is used

The ways in which respondents use the tablet PCs differ. Three levels of use could be distinguished from the questionnaires.

At the most basic level, the tablet PC, together with the software Windows Journal, is used to write on instead of the chalkboard, without change in pedagogy or teaching style.

As formerly with chalk, but on tablet (Respondent 31).

> Tablet PC Windows Journal writes notes while teaching (Respondent 27).

On a next level, respondents prepare notes or slides beforehand and leave space to fill in and annotate in class (e.g. in Windows Journal).

> Prepare and give lectures on Windows Journal (on the Tablet PC) (Respondent 09).

> Prewritten notes and problems. Clips/pictures. Fill in gaps in class (Respondent 16).

> I do my prep on the tablet. I copy sections (problems from the text book) and write on tablet (Respondent 21).

> Use tablet & projector like overhead projector with pre-prepared "slide" with space left for writing (Respondent 24).

At the most advanced level respondents use a combination of different software, such as PowerPoint presentations, Windows Journal, videos and graphing software.

> I teach on a tablet PC using Windows Journal mainly. I intersperse with bits of PowerPoint, YouTube, etc. for visual effect & to make the lecture interesting (Respondent 22).

> Theory on PowerPoint. Problems on Tablet PC (Respondent 10).

The feature of the tablet PC to record writing on the screen together with the voice of the lecturer is not used by any of the respondents to record their lectures. There is one respondent who uses this feature to record his own short videos, but not during lecture periods. In section 6.2 results of the interview with this lecturer are discussed.

5.3.5 Overhead projectors

We saw in Figure 21 and Figure 22 that the use of overhead projectors has not changed significantly over the 10 years from 2003. Only two respondents indicated that they predominantly use overhead projectors with transparencies, with two more that use it about 50% of the time (and 50% chalkboard). These were all male respondents. A few other respondents occasionally use the overhead projector:

> Handwritten slides work for me (Respondent 17).

> What I do [overhead projector] present works well enough (Respondent 15).

> Largely it [overhead projector] economizes time of contact in terms of students' concentration. Time freed to lecturer for other engagements. Lasting stay facilitates students' time of access assimilation of subject matter. [It] removes elements of boredom & interactively engaging (Respondent 18).

Two respondents indicated that they use a computer to produce transparencies with graphs and diagrams:

> Illustrative diagrams and plots are produced with a computer, sometimes using the internet (Respondent 12).

The only problem reported about using an overhead projector is the size of the projection:

> In a good venue, with a class of moderate size, the area covered by the blackboards is larger than the projection screen (Respondent 12)

5.3.6 Other technologies

Technologies, other than chalkboard, overhead projectors, tablet PCs and projectors, used by staff for teaching, are computers (laptops), microphones and cameras.

According to the results displayed in Figure 22, laptops are used for 4.8% of teaching time. PowerPoint presentations are used for displaying theory, but graphical software is also used to illustrate graphs:

> For illustration of graphs of functions and related results (Respondent 29).

A few respondents mentioned the use of microphones for lecturing purposes, especially for the larger classes and lecture halls. Although they did not mention it, most lecturers use microphones in large classes:

> In larger classes I'd make use of more technology, such as microphones, projectors, transparencies (Respondent 14).

"Overhead" cameras are installed in some of the large and newer lecture halls and can be used to zoom in on a pocket calculator, textbook, graph produced on computer prior to class, or project images of the lecturer writing on paper. Only three respondents indicated that they use the cameras at all:

> Display e.g. pocket calculator on camera when necessary/graphs/sketches (Respondent 11).

5.3.7 Problems experienced using technology

Problems experienced by the teaching staff using technology seem to be relatively few. Four respondents reported no problems as all, while ten reported that they occasionally experience problems with hardware that fails (or fails to connect). Five cited lack of facilities in some classrooms, or missing cables and remotes and one respondent mentioned the set-up time as a problem as well:

> Faulty equipment in lecture halls. It takes a while to set things up. If something does not work, I also have to prepare a backup plan (Respondent 13).

One lecturer did not indicate that he uses a camera, but remarked on problems with cameras:

> The cameras with projectors often do not work properly (Respondent 15).

Two lecturers indicated that although they use a tablet PC in class, they limit their use as their handwriting on the tablet PC (in class) is unclear and because it is uncomfortable to write on the screen. Dexterity, described as a key factor by Loch and Donovan (2006) for successful teaching with tablet technology, could be a problem especially for left-handed users while Anderson et al. (2005) also named legible handwriting as a critical factor.

5.3.8 Conclusion

Use of technology for lecturing purposes seems to be influenced by three factors: availability, necessity, and preference/beliefs.

Only three respondents (9.4%) indicated that they use chalkboard and overhead projectors as they do not have access to tablet PCs.

Of the 32 respondents, 11 respondents (34.4%) indicated that they would use technology differently in large and small classes. They mostly indicated that in large classes they would use more technology as visibility on the chalkboard becomes a problem. Therefore, the use of technology becomes a necessity (though it might not be their preference).

The majority of the respondents, however, choose the use of technology based on preference or beliefs, whether it is the chalkboard, overhead projector and transparencies or a tablet PC. It must be said that attitudes and beliefs can be influenced by the example of other lecturers. Preferences can also change as lecturers become more comfortable using new technologies on a regular basis.

5.4 Use of technology beyond the lecture classroom

5.4.1 Introduction

The University of Pretoria makes use of a Learning Management System (LMS), based on Blackboard, known as clickUP. This LMS incorporates different tools that can be used for administration and communication, as well as for academic purposes. Students have access to clickUP on campus via an intranet (or internet), as well as off-campus via the internet. Students have access to the LMS and the internet on campus via computers in computer laboratories, study centres and the library, and access to eduroam via Wi-Fi hot-spots, which allow students to obtain Internet connectivity using their own laptops, tablets and smartphones.

The University of Pretoria has enabled the Blackboard Mobile Learn application, which allows student access to large parts of their clickUP (LMS) content through mobile technology. Blackboard apps are available on various platforms for smartphones and tablets, including BlackBerry, Palm, Apple and Android-based phones and tablets.

5.4.2 Results and discussion

Use of technology by students as a learning tool

From the responses it can be seen that technology, with the exception of the learning management system, is used to a limited extent as a learning tool outside of the formal lecture classes. WebAssign, CAMI Maths and MATLAB are the systems or programmes mostly used by respondents.

WebAssign is a flexible online instructional system that provides assessment, an extensive textbook selection and support, and enhances student learning. It allows the lecturer to create assignments that instantly assesses individual students and whole class performance. WebAssign provides Learning Management System (LMS) integration for Blackboard.

The use of WebAssign is unfortunately not free – registration fees per student must be paid. This fee is usually included in the course fee.

WebAssign is used as an online homework system by three of the respondents in the modules they teach, and six other indicated that WebAssign is used in courses they are involved with, although they are not involved in the administration of the system. Students complete and submit online assignments (for homework in their own time), which also serves as preparation for tutorial classes.

MATLAB is a high-level computer language and interactive environment for numerical computation, visualisation, and programming. With MATLAB, data can be analysed, algorithms developed, and models and applications created. Multiple approaches can be explored. MATLAB is installed on the computers in the laboratories, a site licence is purchased and there is no additional cost per student to use the programme.

MATLAB is used in two ways. Firstly, it is used by students in practical classes for both numerical methods and mathematical modelling modules. It is also used by students, to a limited extent, in some modules (e.g. first year linear algebra) to complete assignments outside of lecture and tutorial classes. Nine respondents indicated that they use MATLAB themselves, or that it is used in modules they are involved with.

CAMI Maths is an educational drill-and-practice software system that allows students to master mathematical skills in a progressive, incremental manner. The syllabus covers pre-school to grade 12. Students receive immediate feedback and positive reinforcement and CAMI Maths can be used for diagnosis, practice and remediation purposes as students' progress is continuously monitored and recorded. The CAMI Maths system is not free, and there is a cost per student payable.

CAMI Maths is used in one first year module in the extended degree programme by three lecturers involved in teaching this module. It is used during a practical face-to-face session with the students in a computer laboratory on campus, with the purpose of practise and drill of mathematical concepts and calculations.

Unfortunately not all mathematics courses are suitable to the integration of the type of technologies described above. Courses based on theorems and proof (Anguelov, Engelbrecht, & Harding, 2001) are not numerical, and online or electronic based assessments cannot be used to assess students.

Use of the learning management system

All modules offered at the University of Pretoria are required to have an online component on the LMS, and it is available to all students registered for that module. These LMS modules mostly communicate information to students, such as lecturer contact information, class schedules and study guides (uploaded at the beginning of a semester), but are also expected to be used during the semester for communication and academic purposes, as is discussed subsequently.

The LMS Blackboard incorporates tools such as Announcements, Email, Calendar, Grade Center, and Groups to be used for communication or administrative purposes. None of the respondents indicated that they use Grade Center, as technical assistants (who were not participants in this study) are usually responsible for compiling and updating mark sheets.

Of the 32 respondents, 28 indicated that they use announcements or the calendar themselves to communicate administrative information to their students (or would use it if they had decision-making rights). Another respondent indicated that he uses it in the modules he teaches, but that someone else administers it on his behalf.

Eight respondents indicated that they use Groups for tutorial classes. This tool allows students to join a group themselves by using a sign-up sheet.

Although the Discussion board on Blackboard can be used as an academic tool to discuss course content, it seems as though it is used more often, but still to a limited extent, by students to communicate with each other on issues such as textbooks for sale and information about tests they are writing. Eight respondents indicated the use of Discussion board.

Apart from uploading the study guide, which contains learning outcomes, at the beginning of a semester, Blackboard also has other tools that can be used for academic purposes. Of these, the LMS is mostly used for sharing course content by uploading lecture notes and memorandums of tests and assignments, for access by students. 29 of the respondents indicated that they use (or would use) the LMS for this purpose.

One lecturer, who mentioned that technology reduced student-staff contact, also mentions some of the advantages of uploading of lecture notes and memorandum:

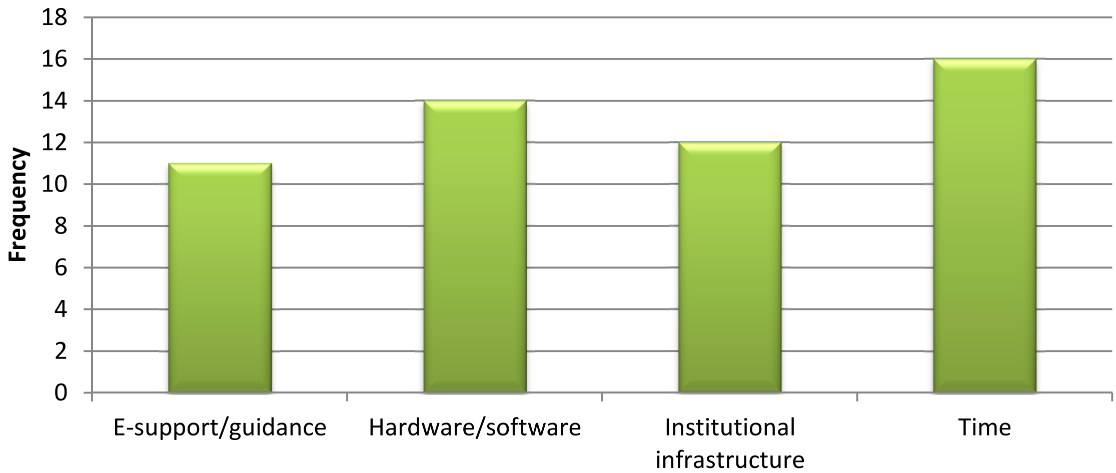
> Students-staff contact eliminated and discourse reduced to non-living facility suffocates healthy relations. ClickUP: Students' access to study material and memos to tests, enhance [learning] long after actual presentation (Respondent 18).

11 respondents indicated that they use online assessments (assignments or tests). Mash-ups allow instructors to include content in a course from an external website, such as YouTube videos, images and PowerPoint presentations. Eight respondents indicated the use of Mash-ups.

The use of other academic tools in Blackboard, such as Blogs and Collaborate (a tool which allows the instructor to communicate online with students on a whiteboard), is extremely limited and takes place only on occasion.

Respondents were finally asked to react to the statement "I would increase my use of technology for teaching if I have more/better…" Results are shown in Figure 23.

Figure 23 I would increase my use of technology for teaching if I have more/better…



It is interesting that 11 of the respondents indicated that they required increased e-support or guidance, and 14 respondents indicated a need for better hardware and or software. Lack of software often means lack of knowledge of software or available technologies.

Opportunities to develop their technological and pedagogical skills are available to staff members of the University of Pretoria. Training courses focusing on the different aspects of the LMS are provided by CE@UP (Continuing Education at University of Pretoria) at regular intervals. Other courses are also offered by them, such as “Optimising whole brain ® learning for the digital age”, which includes skills development to implement a range of educational technologies in a structured way in order to optimise learning. Most of these courses are offered free of charge to academic staff members - attendance however, is voluntary. Unfortunately these courses are focused on aspects of the LMS and are not subject specific.

Time constraints appear be perceived as a barrier to the implementation of new technologies. Research about new technologies available and how they can be used, redesigning learning activities to include the technology into the curriculum and mastering the new technologies can be very time-consuming and daunting.Conclusion

Although the learning management system (Blackboard) offers a variety of built-in tools to enhance blended teaching/learning, it seems as though the only tools used extensively by respondents are the uploading of lecture notes and memorandums, and the administrative use of the announcement tool. Online assignments and tests are used to a limited extent while a few respondents indicated that they use (or would use) discussion board. Mash-ups, such as videos, are also used to a limited extent.

The use of online systems, such as WebAssign and CAMI Maths, is restricted to a few (mostly first year) modules.

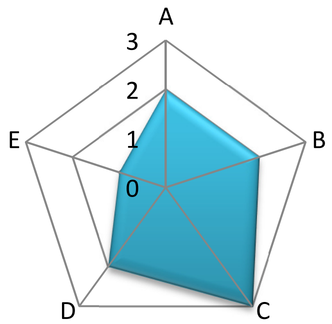
5.5 Measure and rating of lecturers according to their use of technology

An instrument to measure and rate the use of technology by lecturers was developed and discussed in section 3.3. Due to incomplete data, only 30 of the 32 respondents were measured on a scale of 0 to 3 on each of the five radials

A Technology for use by the teacher in the classroom as a teaching tool
B Technology for use by student as a learning tool
C Use of LMS as an academic tool
D Use of LMS as an administrative tool
E Use of technology on a personal level

Respondent 24 is used as an example of how the tool was applied. As this respondent uses a tablet PC for teaching, but less than 66.7% of teaching time, this respondent received a score of 2 on radial A. This respondent himself makes use of the WebAssign system in courses he teaches, and therefore receives a score of 2 on radial B. On radial C this respondent received a score of 3 as he uses the LMS's academic tools extensively, such as in uploading of lecture notes, tutorial videos, blog and discussion board. He received a score of 2 on radial D as he indicated the use of announcements and groups on the LMS. On radial E he received a score of only 1 as he indicated that though he uses a smartphone, he does not really keep up with advances in technology. Figure 24 shows his radar chart.

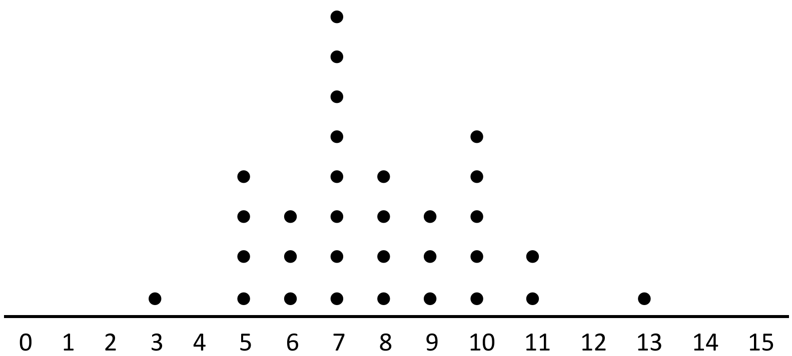
Figure 24 Radar chart of Respondent 24



Respondent 24 receives a rating of 10 on the use of technology scale. It can be said that, even though Respondent 24 does not score high on the scale for personal use, he uses blended teaching quite extensively in his teaching.

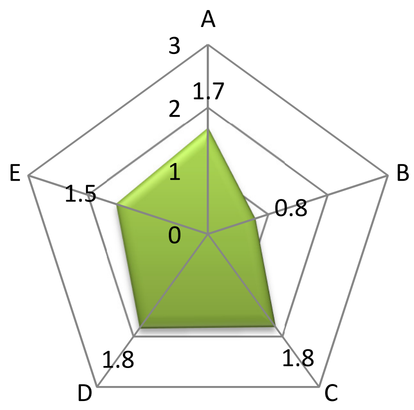
All the respondents were measured and rated accordingly. The modal rating is 7 (out of a possible 15) and the mean rating is 7.6. The lowest rating was 3 and the highest rating was 13. Figure 25 shows the ratings for the use of technology of the respondents.

Figure 25 Ratings for use of technology of respondents



After all the respondents were rated according to the instrument, the average of the rating of all the respondents on each radial were calculated, resulting in a radar chart portraying the "average" respondent in Figure 26.

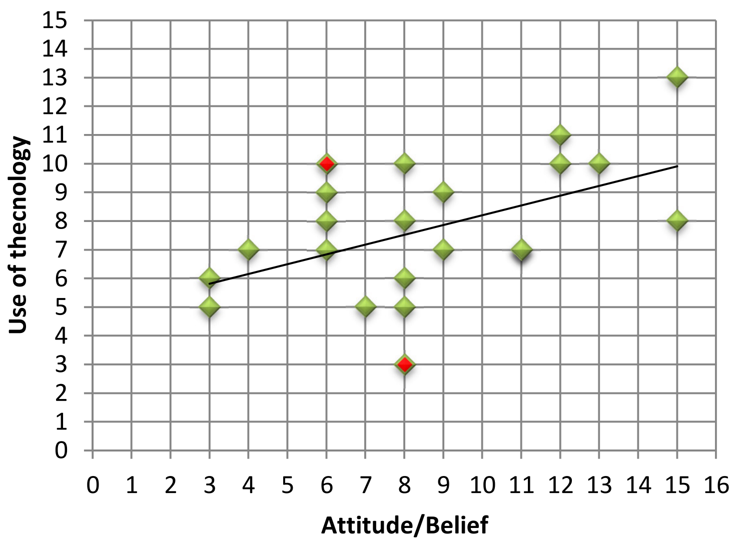
Figure 26 Radar chart of "average" respondent



It can be seen that on average, respondents make use of blended teaching, although their use of technology as a learning tool for students (other than the LMS) is limited.

Figure 27 compares the rating of the respondents' "Attitude and beliefs" against their rating for "Use of technology". As expected, there is a positive correlation between the two ratings. The outliers are of interest.

Figure 27 Attitudes and belief towards technology VS use of technology



One of the outliers received a rating of 8 on the Attitude/Belief scale, but a 3 on the use of technology scale. The rating of 8 for attitudes and beliefs was obtained as this lecturer responded neutral to all the relevant statements. However, in general this respondent uses blended teaching to a very limited extent. He only uses the chalkboard for teaching and the LMS for announcements, groups and uploading of lecture notes/memorandums. This respondent cites "large investment of time required to become confident user of modern technology" and technology failures as reasons why he does not use technology.

Another outlier received a rating of 6 on the attitude and beliefs scale, but a rating of 10 on the use of technology scale. A rating of 6 was obtained as this lecturer agrees with the statements that the chalkboard is still the best way to teach mathematics, and that the use of overhead projectors is a good way to teach mathematics. Although he does not use digital technology when lecturing, this lecturer uses the LMS with announcements, uploading of lecture notes/memorandums, and tests. He also makes use of CAMI Maths as a learning tool for his students during practical classes, and on a personal level uses a smartphone and tends to keep up to date with advances in technology, resulting in a rating of 10.

5.6 Conclusion

In this chapter we saw that, according to their use of technology rating, all respondents to the questionnaire lie spread out on the spectrum of blended teaching, although some of them have barely moved away from the bottom end of the spectrum.

Tablet PCs are used by 40.6% of the respondents to lecture mathematics in class. Even with this aspect of technology there is a spectrum of use – on the one side tablet PCs are used only to replace the chalkboard, especially in large classes where visibility is a problem, and on the other side tablet PCs are used with a variety of software, such as Windows Journal, GeoGebra, PowerPoint and videos, thus blending teaching inside face-to-face classrooms. One of the respondents using this blended approach in the classroom says that technology makes her "bigger and better."

Many factors influence the extent to which lecturers blend their teaching, but one of the main factors perceived as a barrier to the integration of technology into mathematics teaching, is the subject culture of mathematics. This culture holds that mathematics does not lend itself to technology for teaching, especially for courses that are theorem-and-proof based. Due to the nature of some mathematics courses, the use of programmes such as MATLAB is not suitable, and online assessments would be impractical. This does not mean however that technology such as tablet PCs cannot be used for teaching mathematics. Furthermore, the LMS can be used successfully to communicate with students and to upload course content for access by the students – ranging from lecture notes and memorandum to videos or mash-ups.

Other factors identified that influence the integration of technology into teaching include beliefs and attitudes towards technology, lack of technology, time constraints, lack of technology-supported pedagogical knowledge and technological support.

Interestingly, age does not appear to influence beliefs and attitudes of the respondents towards the use of technology for mathematic teaching. Gender emerged as an important factor – female respondents showed them to be relatively more open to accept and adapt to the integration of technology into mathematics teaching. Academic and teaching qualifications appear to influence these beliefs as well.

I did find that most respondents do make use of announcements in the LMS, and also upload lecture notes or memorandums onto the LMS, making it more accessible for students. More than half of the respondents, however, do not use the other tools available to them imbedded in the LMS, such as online assessments (whether as diagnostic, formative or summative tools) or mash-ups, discussion boards or Collaborate.

The use of other technologies as learning tools, such as MATLAB and WebAssign are also limited. Apart from the attitudes and beliefs of the lecturers, integration of these technologies is influenced by the nature of the course and the cost of using the system.

In chapter six more detail on the integration of technologies such as CAMI Maths, MATLAB and WebAssign into specific courses, will be discussed.

CHAPTER 6: INTERVIEWS

6.1 Introduction

A large number of respondents indicated uses of technology in the modules they teach that require interaction of students to various extents. This ranged from uploading class notes and memos onto the LMS that students can download, to programmes where students must actively use technology to complete assignments and be assessed. Three of the four lecturers that were selected to be interviewed indicated that they use technologies such as WebAssign, MATLAB and CAMI Maths, and the fourth lecturer was selected because he indicated the use of blogs, discussions and self-produced videos.

Interviewees were approached based on their practical experience of a particular technology. The opportunity was utilised to briefly investigate their attitude regarding other technologies, in particular where they stand with regards to teaching on the chalkboard or by means of newer technology.

6.2 Interview 1 – Rudi: LMS – Blog, discussion board and videos

Rudi is a senior lecturer in his thirties. He holds a PhD in mathematics and has been teaching mathematics for more than ten years, an activity that he enjoys. Most of the classes he teaches are in excess of 200 students. Rudi uses a smart phone but not a tablet, and claims that he does not particularly keep up to date with advances in technology.

Rudi indicated in his questionnaire that he uses blogs and discussion boards imbedded in Blackboard (the LMS in use) in some of the courses that he teaches, and that he also produces his own tutorial videos to upload onto the LMS. He was asked to report on how and for what purpose he uses each of these.

Blogs

Rudi says that the blogs he writes are purely of mathematical nature. He does not write the blogs as such to discuss material covered specifically in the course content, but rather uses it as enrichment. The blogs are mostly related to the course work:

> …this is what we did in class, this is where it is used, and here is a nice example how it is used.

Sometimes the blogs are about issues not directly related to the course, but aimed at enrichment. According to him, students, although they may read the blog, are unfortunately reluctant to comment.

> In a course for say about 800 students, there would be five or six who would try to converse with you, comment on what you write about in the blog.

It is possible to use mathematical notation and symbols (with effort) in the blogs, as Blackboard now has an imbedded equation editor with a graphical user interface (GUI) – an improvement on the old Blackboard where all the mathematical symbols had to be entered manually in HTML code.

Discussion boards

Rudi uses the discussion board as a platform for students to interact with each other – he simply acts as moderator, in case "something nasty" happens, which has fortunately never been necessary for him, although he is aware of other lecturers having experienced such problems. Students do not use the discussion board for collaborative learning. They can post whatever they want to, such as advertising textbooks, exercises they experience problems with, or what they are writing test on. According to him,

> participation by students on the discussion board has dramatically decreased over the last few years.

Six or seven years ago the discussion boards were used quite active. These discussion boards were one of the only opportunities students had to communicate with their classmates on the internet. Rudi speculates that with the increase of other social media, such as Facebook and Twitter these discussions have mostly been moved there. Students prefer the lecturer not to see what they discuss.

Producing tutorial videos

Initially, Rudi made use of open courseware videos from MIT, but the existing videos were not always exactly what he needed. When he first started making his own videos, he recorded himself with his own digital camera, standing in front of a chalkboard, explaining a concept or doing an example. He notes that

> those files are extremely large, making it difficult for students to access them.

In 2013 he started using his tablet PC and standard recording software on the tablet PC, capturing his writing on the screen in Windows journal and his voice, as he explains a concept or example. Rudi makes these videos mostly for courses that he was strongly involved in during the curriculum development – mainly courses catering for mainstream BSc mathematics students:

> I do not do this for all the courses that I teach. It takes so much time so I need to decide where I want to spend my time and I would rather spend it on students that are important to me.

These video files are much smaller and easier for students to access and download via the LMS. To keep file size smaller, the videos are kept short (maximum five to ten minutes), dealing with only one problem or one concept or theorem per video. He claims that feedback from students about the videos is positive.

Other technologies

Rudi makes use of a tablet PC for teaching, but his use of the actual tablet PC capabilities is limited. He claims that the major reason for this is the fact that with the tablet PC and projector, you only have one screen:

> … you can only display a very small amount of maths at a time.

It is not possible to do examples on the tablet PC, based on a theorem, while displaying the theorem simultaneously on the tablet PC. In a theory-based module, he prefers to prepare for class by writing down his complete lecture on paper, and then writing down all the definitions and theorems to be discussed or referred to in class on the tablet PC, before the class. These are then displayed in class, but the chalkboard is used for teaching – proving theorems and doing examples. In a module that is less theory-based and more problem based, he may go back to use the chalkboard only.

Another reason Rudi offers for preferring the chalkboard is that he finds it difficult to write on the tablet PC – he remarks that it is a completely different feeling writing on the chalkboard with chalk than on “a piece of glass”. Also, bending over the tablet PC is an uncomfortable position to be writing in – not all classrooms are ideally set up with a proper podium. Furthermore, he claims that using the tablet PC to write on in class means you are less active, where Rudi prefers a teaching style where he moves around more in the class. Although a PowerPoint presentation could be used in a similar way as his use of a tablet PC, it is easier to write and less time consuming than to type mathematical notation and Rudi's perception is that students find it easier to read handwritten mathematics.

Rudi indicated that he has to be careful with pacing when going through the theory on the tablet PC (when he uses it as described above). If he writes on the chalkboard and talks in between, students have more time to absorb the mathematics, which is another reason why Rudi prefers the chalkboard. He prefers students not to write down everything written on the board, since he converts the handwritten lecture notes to PDF format and makes it available on the LMS. However, students still prefer to take notes. In future Rudi considers writing an outline of the lecture, and uploading it onto the LMS before class so that students can download and/or print it, completing it in class. According to him, students need to take notes in class should be reduced. However, he feels that such an outline would restrict him, making it difficult to deviate from the outline, if necessary.

6.3 Interview 2 – Andrew: CAMI Maths

Andrew is appointed as a senior technical assistant accredited as a lecturer. He is in his forties, holds a BSc degree and a teaching qualification and was a school teacher before he started lecturing at the university. He has been teaching mathematics for close to 20 years and most of his classes consist of between 50 and 100 students. Andrew uses a cell phone but not a tablet, and considers himself as keeping up to date with technology.

Andrew indicated in his questionnaire that he makes use of CAMI Maths for some of the classes he teaches. He uses CAMI Maths as a drill and practice software package, provided to students.

Purpose

CAMI Maths is used in a pre-calculus module for students in the extended degree programme on first year level, and for students who are doing a four-year education degree. Students mostly use the CAMI Maths programme during practical classes conducted in computer laboratories, with a lecturer present. Students cannot install CAMI Maths on their home computers – it is only available in the computer labs on campus. CAMI Maths must be installed on a network where the computers are connected to the instructor's computer. Students log into CAMI Maths with a username and password.

The purpose of using the programme is the drill and practice of mathematical concepts and algebraic manipulation that students struggle with, such as algebraic fractions. Typically, students would need to complete 20 problems, based on the same concept. They receive encouragement (positive reinforcement) from the programme as they successfully complete the problems. The level of difficulty increases or decreases based on the student's performance:

> It is like having a personal tutor that sits with you.

Problems to be completed are selected beforehand but students also have the freedom to do additional problems.

Student reactions

Andrew states that initially students were slightly negative, because they did not fully understand the programme, but this quickly changed as they started seeing the advantages of using CAMI Maths. On the whole the reaction was highly positive, especially when compared to previous years where students used MATLAB, which they found difficult to use as they did not understand the programming language used in MATLAB. He feels that for students doing the pre-calculus course, CAMI Maths was a much better choice than MATLAB.

Student participation was good. Stronger students completed the problems quickly, while weaker students often had difficulty completing all the problems in class. These students were given the freedom to return to the labs and complete the problems in their own time. As time progressed, students tended to work more in their own time and attended the formal practical sessions less often, but they still had to complete all the exercises given. If a student scored less than 80% for an exercise consisting of 10 or 20 problems, the student had to redo the exercise. Andrew was able to view the complete performance of every student. The marks received for these exercises contributed 5% towards their final mark. The emphasis was not on marks gained but rather on improving their mathematical fluency:

> I told them the marks are not the most important thing here. It is about having a positive experience while helping you to work on concepts that you are weak in.

The change from MATLAB to CAMI Maths had a positive influence on the performance of students. Pass rates were much higher (almost doubled from 42% to 78%) after the switch, although it has to be emphasised that there were many other contributing factors as well.

Problems experienced

The programme is somewhat restrictive with respect to the format of symbols. In some instances a student would, for example, enter $-2 + x$, but the programme wants it as $x - 2$, marking it as incorrect. This is a frustration as the programme does not give freedom to students to solve the problem in different ways. It is expected that in the upgraded version due for release soon, such problematic issues will be eliminated.

Other technologies

Andrew still prefers using a chalkboard and overhead projector for teaching:

> Maybe I have not made the mind shift yet to even think to use a tablet PC.

Because he was a high school teacher for many years, he allows for considerable interaction in lectures. Andrew wants students to follow step by step how problems are solved and how the exposition develops, while making use of colour chalk when explaining. He feels that this may not be so easy to do on a tablet PC, but acknowledges that he does not know tablet PCs well. Furthermore, his classes are not overly large and he does not teach in large venues where visibility is a problem. Transparencies are never used to write on in class:

> On a transparency I write definitions and formula that I want to highlight in class, that would require a lot of time to write on the chalkboard, but it is important that they should see it.

Andrew also moves around in class and says that because he is left-handed, when he writes on a tablet PC his handwriting is messy and difficult to read, while when writing large on the board his handwriting is much better.

6.4 Interview 3 – Kathryn: MATLAB

Kathryn is an influential female professor who is in her early sixties. She has been teaching mathematics for over thirty years and holds a PhD in Mathematics, as well as a teaching qualification. She enjoys teaching and the classes she teaches consist mostly of between 100 and 300 students. Kathryn keeps up with advances in technology and uses both a smartphone and a tablet for personal use.

Kathryn was interviewed as she uses MATLAB in a mathematics modelling module.

Purpose

In the mathematics modelling module students develop mathematical models such as population and financial models. Students attend two lectures and a practical per week, a total of 12 practical sessions per semester. These practical sessions take place in a computer lab where MATLAB is installed. During these sessions students are required to use MATLAB for coding the models developed during the lectures. They are then required to use their MATLAB programmes to answer questions on the models and to solve problems and make predictions.

Although MATLAB is installed on computers in labs on campus, students can also install the programme on their home computers if they acquire a copy of the programme themselves. It is a programme that runs independently, and no internet connection is needed.

At the beginning of a semester students are given an overview of MATLAB, and as the course progresses, students learn to work independently:

> Initially we give students the complete coding, then we give less of the coding, and after two to three sessions we only give the important bits of coding they need, and then they must continue on their own.

Other modules that also use MATLAB are a numerical methods module and a linear algebra module for engineering students where they get two projects during the semester and they have to use MATLAB to solve systems of linear equations. According to Kathryn, MATLAB is also useful for drawing graphs.

Student reactions

Students in the mathematical modelling course study actuarial sciences, computer studies, applied mathematics or pure mathematics. Students do not find MATLAB easy to use, and Kathryn’s perception is that as time has progressed (through years), students seem to find

MATLAB harder to master. The expectation was that students of this generation, who are technologically more skilled, would master MATLAB much easier than they do.

In the past MATLAB was also used for a pre-calculus module for the extended programme and education students. That was not successful as MATLAB was just too difficult for these students to master and contributed to a negative attitude amongst students.

Problems experienced

Students seem to struggle with the logic behind the programming, more than with the technical aspects. The learning curve for mastering MATLAB often seems to be experienced as formidably steep.

Other technologies

Kathryn was the first lecturer to use a tablet PC for teaching mathematics at UP. She uses the programme Windows Journal on the tablet PC to prepare a broad (handwritten) structure of her lectures, and then uses the tablet PC in class to write on, expanding on the existing structure. These lecture notes are then uploaded onto the LMS for students to download. Kathryn intersperses her lectures with graphical software MATLAB and YouTube videos, and occasionally she uses a PowerPoint presentation if the nature of the content she is teaching allows for this. She also makes use of a microphone in class, and regards the technology as making her “bigger and better”, especially since she often teaches large classes of engineering students. Using the tablet PC is now second nature and she says she will not teach any differently even if she teaches small classes.

6.5 Interview 4 – John: WebAssign

John is an enthusiastic thirty year old mathematics lecturer. He is currently working on his PhD in a mathematically rich study in the field of mathematics education. He has been teaching for less than ten years and enjoys it. The classes he teaches consist mostly of over 200 students. John keeps up with technology and uses a tablet for personal use.

John indicated that he uses WebAssign in the calculus modules he teaches, and I approached him for an interview to learn more about his experiences with WebAssign.

Purpose

WebAssign is an online homework system – students have access via a username and password, and need no additional tuition for using it. They can access it on their tablets, computers on campus or at home, any place where they have internet access:

> We see WebAssign as a homework tool, a way to get students to do mathematics outside the classroom.

At school students were forced to do homework every day, whereas at university students often fall into the trap of not being committed because of the new freedom experienced:

> Many students do not realise how important it is to do mathematics problems outside the classroom.

WebAssign activities contribute towards a small percentage of their grades. The system grades assessments automatically, students get immediate feedback and lecturers obtain the grades in an Excel spread sheet file. A student can have up to five attempts to complete a problem, and John usually gives them a week to complete the homework before their next tutorial class.

> The homework has a dual purpose – firstly students are obliged to work outside the classroom, and secondly, it serves as preparation for their next tutorial class.

WebAssign requires of students to only enter a final answer, and do not award partial credit. Statistics on completion time are available. Although the more difficult problems can be assigned more marks per question, by choice John mostly assigns one mark per answer, regardless of the level of difficulty of a question. WebAssign cannot distinguish between conceptual errors and calculation errors. In addition, pen and paper tests are written during the tutorial classes. Here partial credit can be given and a distinction can be made between conceptual and calculation errors. However, where they wrote six class tests per semester tutorial classes in the past, with WebAssign they now only write four or five per semester. With 900 students in a course, grading handwritten tests is time consuming, so by reducing the number of handwritten tests, time spent on grading has been reduced significantly.

According to John an advantage of using WebAssign is that he can reach all students, without requiring much additional time from him to prepare problems, as WebAssign has a large database of problems from which the lecturer can choose in order to compile an assignment. WebAssign problems include multiple choice questions (MCQs), but also questions with numerical answers and questions with algebraic answers, such as indefinite integrals (CRQs). It is often the case that indefinite integrals lead to different formats in answers, but WebAssign usually does accept these different formats – it has an intelligent "marker". John can override a student's score if a student approaches him with a problematic marking issue. According to John, one limitation of WebAssign is that it cannot test theory with proofs, which is a component of some of the courses where WebAssign is used.

Student reactions

John gets positive feedback from students – they enjoy using WebAssign and find it easy to use:

> Students do calculations on pen and paper and enter the answer in a box. They then get immediate feedback. They like the immediate feedback – they know immediately if they are correct and move on to the next question, or if it is wrong and try again.

Another advantage for students is that they can do it whenever it fits into their schedule – they can set time aside for their WebAssign when it suits them.

Some students prefer to do their WebAssign homework in groups and this practice is not discouraged. WebAssign allows variation in the questions by means of changing certain numerical values, so although the method of solving the problem remains the same, the numerical values of the answers will differ. John has a policy of not giving his students help with their assignments – it is their own responsibility, but since it is open book, they can consult their textbooks, or help each other when they have trouble solving a problem. Using WebAssign this way promotes collaborative learning amongst students – they have to communicate with each other about ways to solve a problem. If they do assignments in groups, they learn other skills as well and also communicate mathematics. Again, what is important is that they think about mathematics outside the classroom, and do not enter the tutorial class under-prepared. John feels that they have a better foundation when entering the practical session, and more advanced problems, where it is necessary to "dig deeper", can be done in the tutorial classes.

Problems experienced

Initial registration and login problems were experienced such as entering their national ID-numbers instead of their student numbers and forgetting their usernames and passwords. Such administrative problems require time from the lecturer for sorting out. WebAssign intends to appoint a local administrator who will be able to help with these problems on site. There is a cost per student attached to using WebAssign and it is included in the course fees. It is important therefore that lecturers and students make the most of it and ensure that students benefit from it.

An analysis done by John in one module, showed a strong positive correlation between student grades for WebAssign and their semester test performance. No research has yet been done on how the introduction of WebAssign has affected grades and pass rates. John's perception is that the average students are the ones that should benefit most by WebAssign, as it gives students more motivation to do mathematics outside the classroom and gives them confidence that they can do the work.

Other technologies

According to John, a major advantage of using a tablet PC for teaching is that he does not turn his back to students:

> I feel that I am more in control of the class.

John says it is easier to keep an eye on the class, and because you do not waste time on things like having to erase the chalkboard in between examples. Many of the classrooms are not suited to use of the chalkboard, due to the size of the venue when teaching large classes. John handles the problem of having only one computer screen to display at a time by writing the theory (theorems) on the board, and leaving it there for the duration of the class, while doing all the applications on the tablet PC. An advantage of teaching on a tablet PC is that if a student asks a question after class regarding the first problem done, it is possible to scroll back and answer the student immediately, as the info has not been erased and lost. There is often more than one method to solve a problem, but choosing to solve one problem using different methods, usually means there is not enough time in class to do a variety of examples. John gives additional examples as homework and the solutions, written on the tablet PC, are then easily posted on the LMS. John embraces the use of technology in education:

> Because we live in a new technological age, we cannot ignore it. People change, and we have to change with them. We cannot teach as they taught a century ago.

6.6 Discussion

Use of technology

Wallace and Young (2010) stated the following three main goals of moving towards a practice of blended teaching and learning:

- to make learning more accessible and flexible for students,
- to improve teaching practices and learning outcomes, and
- to improve use of available resources.

According to Bitner and Bitner (2002), the stimulus for the use of technology in education should be to enhance learning. Although each of the four interviewees has different goals and reasons why they use the chosen technology, the common goal is to enhance learning. How each of the technologies is used, depends on the purpose of using that technology and it differs from technology to technology.

Both Kathryn and Andrew use MATLAB (in the mathematical modelling course) and CAMI Maths (pre-calculus course), respectively, as an integral part of the classroom activities during formal face-to-face contact sessions with students in computer laboratories. Since there is an instructor available during these sessions, the students are provided with support, although they can also access these technologies in the labs in their own time to increase flexibility. Unfortunately CAMI Maths is only available to students in computer laboratories on campus, while students can download MATLAB to their personal computers if they acquire a copy of the programme themselves.

Their purpose for using the technology differs completely. CAMI Maths is mostly used for the purpose of drilling in (fluency) of mathematical calculations and algebraic manipulations. MATLAB on the other hand is used in the modelling course as a tool to implement the mathematical models developed in lecture classes and address certain questions.

John does not use WebAssign in his calculus course during formal contact time with students. He uses WebAssign with a dual purpose – firstly it is used to gently “force” students to do homework and engage with the course content, and secondly to prepare for tutorial classes. Students access WebAssign via the internet (from any computer that has internet access) and in their own time – making learning more accessible and flexible for students. Since John does not offer support to students for their WebAssignments, they are obliged to make use of their personal learning networks (PLNs) if they do not understand the content. Students can access various sources of information, such as the textbook or YouTube videos. Some students form study groups in which they work together – in other words, they practise collaborative learning. This approach is neither encouraged, nor discouraged by the lecturer.

WebAssign and CAMI Maths are both used as formative assessment tools. In CAMI Maths a student answers questions step by step. The student’s procedure is therefore assessed to some extent by the program, although it does not allow for great flexibility. In WebAssign students only enter the final answer, so the students’ procedures are not being assessed – a shortcoming in most EEBs, according to Cazes et al. (2006).

Both WebAssign and CAMI Maths grade students’ attempts and students receive immediate feedback and grades from the programme. These grades are available to the lecturers and in both cases these grades contribute a small percentage to students’ semester marks. Especially in courses where there are a large number of students enrolled, this feature is important as it reduces the need for grading handwritten tests. The immediate feedback and marks motivate students to do the problems that they are required to do.

MATLAB does not grade students’ attempts. Students receive marks for the answers they provided on worksheets which are handed in at the end of a practical session.

Rudi uses his blogs, discussion boards and videos for different purposes. As he uses the LMS as platform, learning is both accessible and flexible.

His blogs are written as enrichment related to, but not covered by, the course curriculum. By writing his blogs, he aims to make students who are interested in pure mathematics think more broadly than the course content, to stimulate their minds, and invite students to comment on the blogs. Since these blogs cover topics not covered by the curriculum, these blogs cannot be seen as an essential part of the course – students who do not read the blogs, are not disadvantaged in the course by their lack of participation.

Rudi's tutorial videos, however, can be seen as an extension of his face-to-face contact sessions, as the content of the videos is covered by the curriculum itself. His videos are used to show examples or proofs not done during class. Although these additional examples and proofs could also be typed or handwritten and uploaded as documents onto the LMS, using videos has distinct advantages. According to Galligan et al. (2010), documents display statics text, similar to text book, while using the capabilities of the tablet PC allows the lecturer's explanation to be recorded as he is writing it.

Usually the purpose of a discussion board used as part of a course is to encourage discussion between students about the course content, making it part of their personal learning network (PLN). Here mathematics is at a distinct disadvantage, as mathematics uses a symbolic language that makes it difficult to type. Although Blackboard provides a GUI on computers for mathematical notations, it is quite tedious and time-consuming to use. Unfortunately this GUI is not available on Blackboard Mobile and according to Bonk, Kim and Zeng (2005) blended learning will increasingly involve mobile technologies. Rudi therefore uses the discussion board purely as a tool for communication among students, and as there are many other platforms available for this purpose, where the students can control who reads their comments, students now make little use of the discussion board.

Student reaction

Students' reaction and attitude towards the technology they are required to use also differ. Feedback on both WebAssign and CAMI Maths is positive overall. Both these programmes are experienced to be easy to use.

On the other hand, students do not feel as positively towards MATLAB as they find it difficult to use, and the learning curve is quite steep.

According to Rudi, although students view his blogs, only a few students comment or react to these blogs. Rudi does however report positive feedback regarding the tutorial videos which he produced.

Chalkboard/Tablet PC

Although the interviews provided more detail as to how the lecturers use the teaching technologies in their classes, it did not provide much deeper insight into the reasons for preferring the use of the chalkboard or tablet PC, other than that obtained from the questionnaires.

Two aspects will however be highlighted. Kathryn and John, who both primarily use the tablet PC for teaching, use the technology because we live in the age of technology. They also both feel that it allows them to be better lecturers as it empowers them.

Rudi and Andrew on the other hand, seem to be strongly influenced by the subject culture of mathematics. Andrew has not used a tablet PC yet, but he indicated a resistance to the idea of writing on the tablet's screen as he is left-handed, claiming that it would be difficult to write legibly. Although Rudi does make use of a tablet PC (and other technologies as described above), he also still prefers to teach his face-to-face classes using the chalkboard, and he feels much more comfortable writing on the chalkboard than on a tablet PC. Competency and dexterity with the tablet technology (Loch & Donovan, 2006) appear to influence the preferred use of the chalkboard.

6.7 Conclusion

Technology can be used in different ways and for different purposes to add value to mathematics teaching. Technology is used for simple purposes such as sharing or enriching the course content, implementing models in applied mathematics, doing homework, improving mathematical fluency and assessment.

Some of these technologies are expensive to use – both WebAssign and CAMI Maths require a fee per user. This implies that planning of the learning activities must be carefully done as to optimise learning and take into account the available resources.

The nature of the course content limits the use of certain technologies – it is not easy to test theoretical content using technology, although even theoretical courses can be enhanced by the use of blogs and videos.

Although implementing technology does not come without problems, it seems as though the advantages mostly outweigh the disadvantages, especially where technology is used for drilling, homework and assessment purposes, both to the student and to the lecturers.

Whether they use a tablet PC or a chalkboard remains the personal preference of the lecturer, although large class sizes increase the necessity of using a tablet PC for visibility purposes.

CHAPTER 7: CONCLUSION

7.1 Introduction

The purpose of this case study was to explore the use of technology at a mathematics and applied mathematics department at a South African University.

The research study combines data from questionnaires and interviews with selected participants. Data were analysed, directed by the research question and sub-questions. The study was informed by the following research question:

> **To what extent is a blended teaching approach currently used by lecturing staff for teaching mathematics at undergraduate level?**

and sub-questions:

1. What are the attitudes and beliefs of the teaching staff with respect to the suitability of using technology for teaching mathematics?
2. What technologies do the teaching staff prefer to use? To what extent are these technologies used when lecturing undergraduate mathematics inside the classroom? How has this changed over the last ten years?
3. Do the teaching staff make use of the learning management system (LMS) as a tool for administration and communication purposes as well as for academic purposes? Do they use any other technologies as a tool for learning outside the classroom?

We first address the sub-questions and then consolidate in order to answer the main question.

7.2 Interpretations and synthesis of findings

1. What are the attitudes and beliefs of the teaching staff with respect to the suitability of using technology for teaching mathematics?

In the literature review, several factors were identified that affect the successful integration of technology into teaching. Two of these factors – the beliefs and attitudes towards technology held by teachers, and subject culture (Hew & Brush, 2007), lie at the root of this research question. Although a staff member may have a positive attitude towards technology, subject culture may deter the staff member from integrating technology into his/her teachimg if it is not in line with the subject culture, content, pedagogy and assessment. (Hennessy, et al., 2005; Hew & Brush, 2007). Mathematicians especially seem to have a strong subject culture.

The study shows that about half of the staff members feel that the chalkboard is more suitable than technology for teaching mathematics. This finding supports the idea of a strong subject culture. There is also an element of resistance to change involved, leading to a hesitance to explore new possibilities. Even using transparencies is supported by more of the staff than not.

Surprisingly then, more staff felt that mathematics is a discipline that lends itself to the use of technoloy for teaching than not. Technology is therefore not considered as unacceptable by this section of the staff and is acknowledged as such but the mode of choice is still the chalkboard for this section of the staff corps. There is even recognition that technology adds value to teaching, though it is still surpassed by the chalkboard. A strong subject culture, however admirable, should not stand in the way of innovation in teaching practices.

Reasons provided for this preference again indicate the existence of a strong subject culture in mathematics, and resistance to change, that could lead to misconceptions, such as the perception, that when teaching with technology, content is necessarily presented in static form that makes it inferior to chalkboard teaching.

Subject culture prevails even among staff members who use a tablet PC. Almost half of these prefer to use the chalkboard instead of new technology when teaching small classes. They only use the tablet PC as writing on the chalkboard is not always visible in large classes. On the other hand, the other half are convinced of the value of technologies that are suitable for teaching. They embrace the capabilities of the tablet PC, and explore ways to use it innovatively and not merely as a replacement of the chalkboard. They carry the belief that they are better and more efficient teachers using this technology.

Teaching of large groups, characteristic of this department, has in some way necessitated the use of technology. There is a trend of moving towards using tablet PCs and staff members who are using these have a strong positive attitude about this issue. A shift in attitude towards technology use in teaching is perceived in this study.

An attempt was made to determine whether certain characteristics of the staff corps, namely age, gender, academic qualifications and teaching qualification, are factors that influence the peferences. An unexpected finding was that age did not emerge as a factor contributing to a preference of the chalkboard over technology. The belief that mathematics is a discipline that lends itself to the use of technoloy for teaching is prevalent amongst all the age groups.

Gender emerged as a factor contributing to a preference for technology over the chalkboard for teaching. The subject culture is strongly rooted under the male staff members, with more than half of them showing a preference for using the chalkboard. Although some of the female staff are also influenced by this subject culture, overwhelmingly more female staff feel positive towards the use of technology for teaching mathematics.

Academic qualifications were also found to be a factor contributing to preference. The higher up on the ladder of qualifications, the stronger the belief in the blackboard for teaching. Although this is not an unexpected finding, the fact that leadership is situated amongst higher qualified staff members may be a deterrent for promoting technology for teaching. A drive towards using technology, spearheaded by the leaders in the department should go a long way towards affecting significant changes. It should be noted that an individual could drive such an initiative, despite a general adverse attitude towards technology amongst senior staff members.

A teaching qualification also emerged as a factor contributing to a preference of using technology for teaching. Those holding a teaching qualification felt more strongly that mathematics is a discipline that lends itself to the use of technoloy for teaching and are more willing to explore and use new technologies. There is a caution for causality conclusions here as more females hold teaching qualifications than males.

One must take into account that attitudes and beliefs are not cast in stone. Both attitudes and beliefs can be influenced or changed, especially by experiences of the individual, and by the example set by others.

The staff member, who first started using a tablet PC in 2003, is a renowned researcher in the field of mathematics education, with a special interest in the use of technology. As she is a role model to her colleagues, her example and guidance showed colleagues the advantages of using a tablet PC for teaching mathematics, influencing their attitudes and beliefs towards using technology for teaching. More staff members started using this technology, and eventually the department made funds available to acquire more tablet PCs. The influence she exuded could explain why staff members of this department are more positive and open towards technology for teaching.

2. What technologies do the teaching staff prefer to use? To what extent are these technologies used when lecturing undergraduate mathematics inside the classroom? How has this changed over the last ten years?

The preference of teaching staff with respect to the technologies that they use for teaching has been discussed when addressing the previous question on beliefs and attitudes. We now address the extent to which technologies are used inside the classroom and in particular how this has changed over the last ten years.

The study shows that ten years ago staff members overwhelmingly preferred the chalkboard for teaching. Overhead projectors were also used, while the use of modern technology was practically non-existing. By 2013 the picture had changed dramatically. Use of the chalkboard decreased significantly, while the use of modern technologies, such as the tablet PC, has increased significantly. This is not an unexpected finding as teaching possibilities evolve over time and it stands to reason that staff at a prominent South African university should keep up with the times as much as possible. The technologies used are chalkboard, overhead projector, laptops, tablet PCs and overhead cameras, often in combination.

Looking at the five phases identified by Hooper and Rieber (1999) in the use of technology for teaching: familiarisation, utilisation, integration, reorientation and evolution, it is apparent that, with respect to using technology for teaching, the department as a whole has moved over the last ten years from the familiarisation phase, through the phase of utilisation and into the phase of integration. There are individuals who have chosen not to enter even the familiarisation phase, and as such should be respected for their choice.

Others have moved even further by reorientating themselves time and time again as technology evolves, following the evolution phase in their teaching.

Factors that appear to prevent lecturers from entering a next phase include the following: subject culture, beliefs and attitudes towards technology, lack of and access to technology, technological skills and competencies, lack of technology-supported pedagogical knowledge, time constraints, and availability of technological support.

Of interest is the continued and unabated use of the overhead projector for teaching purposes. Over a ten year period usage has remained more or less constant. There do not appear to be strong advocates of using the overhead projector as there are for the chalkboard and yet it has unobtrusively remained a stalwart in teaching. Using an overhead projector is taking a step away from the chalkboard but not quite adopting newer technology either. The overhead projector has benefits such as being able to prepare content before the class but does not offer benefits of large screen projections or the ease of posting lectures on the LMS. It can be speculated that as the setting of large lecture halls evolve and the space for overhead projection is limited, the overhead projector may become a relic of the past.

3. Do the teaching staff make use of the learning management system (LMS) as a tool for administration and communication purposes as well as for academic purposes? Do they use any other technologies as a tool for learning outside the classroom?

The study showed that the majority of teaching staff make limited use of the LMS, with a main focus on communication and academic purposes such as sharing of content knowledge. The LMS is used to a much lesser extent for assessment and administration.

In most cases, the above-mentioned uses of the LMS did not require a high degree of innovation or adaptation of teaching strategies. Therefore, although the LMS contributes to blended teaching, the department’s use in general concurs with what Wallace & Young (2010) and Graham et al (2003) describes as serving primarily as an add-on to the course, improving access and flexibility without enhancing teaching practices or learning outcomes This is a possible danger that Wallace and Young (2010) warn against, suggesting that blended learning should not be a mere add-on to a course but should be pedagogically sound.

The use of technology as a learning tool for students outside of the LMS was found to be even more limited. A small number of staff members are involved in courses where other technologies are used, although not all of them are personally involved in the management of the technologies. However, the majority of the staff members do not make use of any learning technologies outside of the LMS.

Although determining the reason for this limited use was not the focus of the questionnaires and interviews it would be reasonable to assume that the attitudes and beliefs towards the use of technology in mathematics teaching as identified above was probably a contributing factor. It also became clear that time constraints hampered many staff members in their willingness to explore the use of technologies. Another contributing factor is that many of these technologies involve costs and the use of these technologies must therefore be supported by the department before it can be integrated into a learning programme.

7.3 The research question

> **To what extent is a blended teaching approach currently used by lecturing staff for teaching mathematics at undergraduate level?**

Although the technological profiles for individual staff members vary widely, the study has shown that on average, teaching staff in the Department of Mathematics and Applied Mathematics at the University of Pretoria, do make use of technology for teaching, and therefore blend their teaching. It can be said however that their use of technology does not always satisfy the definition of blended learning as stated in our literature review, namely the combination of face-to-face teaching with a variety of technologies, utilising the advantages of both to create an optimum programme. For various reasons, many of the benefits offered by technology are under-utilised and the use of technology does not necessarily lead to improved learning.

Increased implementation of blended teaching should benefit both students and teaching staff. As Graham et al. (2003) claim, students should benefit from improved pedagogy and increased access and flexibility of learning. It should encourage exploratory and self-paced learning. Ideally, the optimal use of blended learning should enlarge students' PLEs (Personal Learning Environments). If this does not happen and the use of technology does not go beyond that of mere add-ons, it may be an empty and a somewhat superficial approach.

Large classes typically lead to passive learning situations. Blended learning can counter this as it promotes moving away from the traditional transfer of knowledge towards a more learner-centred approach (Padayachee, 2010). Integrating new technologies, such as the planned use of clickers in selected courses in 2015, could serve the purpose of making students more active participants during lectures. There is a danger that administrative problems, and staff who are not proficient in the application of such technologies, may waste valuable contact time with students. This should be planned for and not discourage staff members to explore, as the implementation of all new technologies will require a learning curve.

Staff could further benefit from blended teaching as the introduction of new learning technologies could give staff more time to do research while at the same time maintaining quality teaching (Hannan, 2005). The case study revealed that a minority of the staff members have teaching qualifications and this could influence their ability to design learning activities that are based on sound teaching principles. A large number of respondents indicated that they would benefit from increased guidance in the implementation of technology in the context of teaching. This is a key issue as a lack of technology-supported pedagogical knowledge has been identified as a factor that inhibits the integration of technology into teaching practices (Hew & Brush, 2007).

Finding the optimum combination of technology and face-to-face teaching, will most certainly require forms of redesigning the curriculum which in turn demands investments of time on the part of the teaching staff and many of the respondents indicated that time pressures was an issue to them.

An area in which the staff members are well-supported by the department and institution, is that resources are made available for the use of technology and training in the use of the LMS is offered free of charge, pointing to commitment from figures in authority to aid staff in their use of technology in teaching. Innovations in teaching and learning are recognized by the education innovation awards at institutional level. The annual "Excellence in Teaching Award" in the Department of Mathematics and Applied

Mathematics is instrumental in motivating staff member of the department to innovate their teaching practices.

7.4 Recommendations

Since innovation in teaching technologies tends to be subject specific, it is important to encourage innovation within a department or subject.

Staff members should be encouraged to utilise the opportunities for the sharing of knowledge and proficient use of technologies already existing within the department. Mentoring could add a valuable dimension to this exchange.

Benefits of the effective use of blended teaching should be shared amongst staff, so that those who are reticent to experiment with technology can recognise the rewards or benefits it may offer them.

The use of tablet PCs by staff in the mathematics and applied mathematics department of UP for teaching purposes is quite progressive and extensive, and through collaboration between mathematics departments of other universities, examples of best practices in the use new technologies could be exchanged. Sharing the results of this study with mathematics departments at other HE institutions in South Africa is strongly advised.

When introducing innovative strategies, it would be useful to remember that innovation in mathematics is a slow process (Buteau & Muller, 2006) and that team-work in redesigning programmes may have longer-lasting success than isolated efforts of individuals.

7.5 Suggestions for further research

The following are suggestions for further research:

- Similar studies can be conducted at other South African universities.
- This study was done from the perspective of the lecturers. Research about the perceptions of students with respect to the technologies could add a valuable dimension to a project like this.
- Since this study did not include pedagogies and teaching style, further research could be done to include this aspect of teaching mathematics with technologies.

7.6 A final word

This case study attempted to reflect the current use of technology at a mathematics department at a research-intensive university in South-Africa. As pointed out by Hannan and Silver (2000), equality between research and teaching is an important factor that encourages innovation in teaching and learning. Where priority is given to research, this can have two possible outcomes: it can obstruct innovation in teaching (Hannan & Silver, Innovating in higher education: teaching, learning and institutional cultures, 2000) or can lead to the introduction of new learning technologies because of the need to give staff more time to do research while at the same time maintaining quality teaching (Hannan, 2005).

The question that can be asked is whether the increasing focus on research at this department will stand in the way of innovation or indeed encourage it?

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APPENDIX A Ethical clearance

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

ETHICS COMMITTEE

Faculty of Natural and Agricultural Sciences

07 October 2014
Dr A Harding
Department of Mathematics
University of Pretoria
Pretoria
0002

Dear Dr Harding

EC140807-071 Blended teaching: use of technology for teaching undergraduate mathematics at the University of Pretoria

Your application conforms to the requirements of the NAS Ethics Committee.

Your attention is drawn to the policy from the Registrar's Office and endorsed by the Senate Sub-committee on Research Ethics and Integrity that student performance at UP should not be used in a publication that might suggest UP as a benchmark or that UP students are a representative sample of students in the subject in South Africa. If an article is prepared for publication, it should have the approval of the Ethics Committee to ensure compliance with this policy. It is also necessary to note that differentiation among students in terms of ethnic, gender or any other identity or criteria must be dealt with sensitively. Please take the liberty to call me should you wish to obtain more clarity in this regard.

Kind regards

Prof NH Casey
Chairman: Ethics Committee

Agriculture Building 10-20
University of Pretoria
Private bag X20, Hatfield 0028
Republic of South Africa

Tel: 012 420 4107
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APPENDIX B The questionnaire

Questionnaire: Use of technology by lecturers in the Department of Mathematics and Applied Mathematics, University of Pretoria

My name is Anneli Billman and I am currently doing my MSc in Mathematics Education under the guidance of Professors Ansie Harding and Johann Engelbrecht. I have a specific interest in the use of technology in such a way that it adds value to the teaching of Mathematics.

The following questionnaire is part of my study undertaken to investigate the use of blended teaching by lecturers in the Department of Mathematics and Applied Mathematics at the University of Pretoria.

Please complete the questionnaire as honestly as possible. Your participation would be highly appreciated. All responses will be treated strictly confidentially and if you are willing to participate in further interviews, your identity will still be protected.

Further Interviews

If you would be willing, after completing this questionnaire, to participate in a follow-up 15 – 30 min personal interview, please provide the following contact information:

Name: ____

Contact number: ____

Best time of day to contact respondent: ________________________________

Hatfield Campus:
After completing the form, please place the form in the marked dropbox in the corridor next to reception in the Maths building, and sign next to your name on the staff list provided.

Mamelodi Campus
After completing the form, please hand the form to Bridgette Yani in D301 and sign next to your name on the staff list provided.

Completion of this questionnaire by staff of the Department of Mathematics and Applied Mathematics is acknowledged and supported as integral to the academic activities.

____

Prof R Anguelov (HOD)

Questionnaire for use of technology for teaching by lecturers in the Department of Mathematics and Applied Mathematics

Answer each question by **circling** the appropriate number(s) in the **shaded box** or by **writing** your opinion in the space provided.

A DEMOGRAPHICAL INFORMATION:

Respondent's number

1 Gender

Male	1
Female	2

2 Age:

20 – 29	1
30 – 39	2
40 – 49	3
50 – 59	4
60 or older	5

3 Country of origin:

South Africa	1
Other (please specify)	2

4 What is your highest academic qualification?

Bachelors	1
Honours	2
Masters	3
Doctorate	4

5 Do you have a formal teaching qualification?

Yes	1
No	2

6 Years of experience teaching/lecturing mathematics

0 – 9 years	1
10 – 19 years	2
20 – 29 years	3
30 years or more	4

7 Is your Cellular phone a smart phone?

Yes	1
No	2
I don't use a cellular phone	3

8 Do you use a tablet (e.g.Apple iPad/Samsung) (for any purpose) ?

Yes	1
No	2

B USE OF TECHNOLOGY IN THE CLASSROOM

9 What size classes do you mostly teach?

0 – 20	1
21 – 50	2
51 – 100	3
101 – 200	4
larger than 200	5

10 Approximately what percentage of your <u>undergraduate</u> lecturing/classroom time throughout a semester do (did) you spend using these different types of technology in 2013 (now) and 10 years ago (then)? (Sum to 100%) (If you started teaching later than 2003, indicate the situation at that time)

	Now	Then
Blackboard & Chalk / White board & Marker		
Overhead projector and transparencies		
Computer/laptop & projector – (e.g. PowerPoint presentations)		
Tablet PC & projector		
Tablet (iPad/Other) & projector		
Clickers		
Camera & projection		
Other (Specify)		
	100%	100%

11 Would you use technology in your classroom differently for large classes than for smaller classes? If so, please describe.

____

____

____

12 Which software packages/apps do you use for teaching?

Scientific Workplace/Notebook	1
TeX	2
MS Word	3
Excel (e.g. solver tool)	4
PowerPoint	5
Matlab	6
Mathematica	7
YouTube video's	8
Internet	9
Other (Specify)	10

13 **How do you use modern technology in a typical class? If you do not use modern technology, move to the next question.**

____

____

____

____

14 **Why do you use modern technology in your classes/ Why don't you use modern technology in your classes?**

____

____

____

____

____

15 **What are the problems you experience when teaching Mathematics with the use of technology?**

____

____

____

____

C **USE OF TECHNOLOGY OUTSIDE THE CLASSROOM**

16 **Do you usually type the test/exam papers and assignments you set yourself?**

Yes	1
No	2

17 **If you have/had decision making right in the modules you teach, which functions of clickUP do/would you use?**

	Use it myself	Let someone do it for me
Announcements/Calendar	1	10
Uploading of lecture notes/memo's	2	11
clickUP assignments	3	12
Online clickUP tests	4	13
Mashups (e.g. YouTube videos)	5	14
Discussion boards	6	15
Collaborate	7	16
Groups (sign up sheets)	8	17
Other (Specify)	9	18

18 Do you make use of any other online/internet facilities to teach students outside the formal classroom (e.g. Practicals, assignments)?

	Use it myself	Let someone do it for me
WebAssign	1	6
MATLAB	2	7
Mathematica	3	8
Excel	4	9
Other (Specify)	5	10

D ATTITUDE TOWARD USE OF TECHNOLOGY

Please read the following and indicate whether you agree or disagree with each of the following statements:

19 I keep up with general advances in technology.

Strongly agree	Agree	Neutral	Disagree	Strongly disagree

20 Even with modern technology available, I still believe the best way to teach Mathematics is the use of a blackboard and chalk/whiteboard.

Strongly agree	Agree	Neutral	Disagree	Strongly disagree

21 Using an overhead projector and transparencies is a good way to teach Mathematics.

Strongly agree	Agree	Neutral	Disagree	Strongly disagree

22 Mathematics is a discipline that lends itself to the use of technology for teaching.

Strongly agree	Agree	Neutral	Disagree	Strongly disagree

23 Using technology adds value to my teaching.

Strongly agree	Agree	Neutral	Disagree	Strongly disagree

24 Please indicate on the scale below where you would place yourself.

I enjoy teaching	1 2 3 4 5	I don't particularly enjoy teaching

25 Please indicate on the scale below where you would place yourself.

I use technology in the classroom	1 2 3 4 5	I don't use much technology in the classroom

26 I would increase my use of technology for teaching if I have more/better

E-support/guidance	1
Hardware/software	2
Institutional infrastructure (e.g. wifi)	3
Time	4
Other (Specify)	5

Thank you for your participation!