PRINT: ISSN 0975-1122 ONLINE: 2456-6322
Int J Edu Sci, 10(3): 410-418 (2015)
DOI: 10.31901/24566322.2015/10.03.06

The Use of Technology Based Tools in Mathematics Teaching at One University in South Africa

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KEYWORDS Elmo. Lecturer. Moodle. Sketchpad. Technological Pedagogical Content Knowledge

ABSTRACT Technology has impacted every aspect of the human lives and as lecturers within Higher Education the researchers need to ensure that they are capable of transforming human practices to suit the requirements and learning styles of the technology savvy students. Moreover, research has shown positive developments in the teaching of mathematics through the use of technology based tools, thus, this qualitative study explored the lecturers' views on the use of technology in mathematics teaching. This study was located at one university in KwaZulu-Natal (KZN), South Africa and was framed within the ambits of teacher[1] knowledge. Qualitative data was collected during the 2013 and 2014 academic year from 12 mathematics and mathematics education lecturers via a questionnaire and semi-structured interview schedules. Thematic coding and interpretive techniques were used to analyze the data gathered. The findings are important for advancing mathematics curriculum development and may be useful to mathematics lecturers at institutes of Higher Education.

INTRODUCTION

Technological advancements have made their way into 21st century educational milieus and the use of technology in teaching[2] is regarded as a responsive and innovative pedagogical tool (Naidoo 2014). Similarly, Shallcross and Harrison (2007) maintain that the use of technology has increased immensely within educational environments. Research (Bennison and Goos 2010; Holmgren 2015) has also shown positive developments in teaching through the use of technology based tools, however the application of these tools within the teaching of mathematics has been inadequate (Drijvers et al. 2010; Joubert 2013).

Objectives of the Paper

This paper sought to answer the following research question: What technology-based tools are being used by mathematics lecturers within higher education? With the move to incorporate technology within educational milieus (Mosenson and Johnson 2008; Judd 2015), research on teaching in Higher Education has intensified with a special focus on the use of innovative teaching methods (Collins 2013). Technology plays an important role in teaching in the 21st Century (Mosenson and Johnson 2008; du Toit 2010; Carceller et al. 2015), however if a teacher is not adept at using this technology effectively or correctly this could have a negative effect on the educational milieu (van Wyk et al. 2010; Çevik et al. 2015). Hence, the teaching aids and resources that one uses must complement the activity and enhance student understanding in order to be effective within any educational milieu.

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Technology and Mathematics Teaching

Educational milieus are pliable and shifting (Anthony and Walshaw 2009) due to the influx of students who are diverse in their backgrounds, needs and aptitudes. If teachers want to prepare students to participate successfully as global citizens (Alsina 2002), there is a need to transform the traditional educational milieu (Yelland 2001; Judd 2015). Since technology has impacted every aspect of human lives and students today are fast becoming technology savvy, teachers ought to know how to use technology based teaching aids to their fullest potential (Mosenson and Johnson 2008).

The benefits of using technology in mathematics are well recognized (Bennison and Goos 2010; Drijvers et al. 2010) and the use of information and communication technology (ICT) within mathematics educational milieus creates many opportunities for students to work within a global technological platform. Moreover, within mathematics educational milieus, technology influences the mathematics being taught and supports the mathematics learning of students when integrated appropriately within the educational milieu (Li and Edmonds 2005; Centre for Technology in Learning 2007; Lin 2008). For example, through the use of calculators, computers and dynamic software, students can study complex abstract mathematics concepts (Franz and Hopper 2007; Bennison and Goos 2010). Additionally, the use of technology within the mathematics educational milieus when integrated suitably with teaching methods, policy documents and assessments has proved to support learning and has demonstrated an improvement in the students' mathematics achievement (Centre for Technology in Learning 2007; Lin 2008).

Theoretical Framework

The paper was framed by merging Shulman's (1987) PCK and Mishra and Koehler's (2006) TPACK frameworks. The lecturer questionnaire assisted in answering questions relating to each participant's pedagogical content knowledge (PCK) and technological pedagogical content knowledge (TPACK). A mathematics lecturer with good pedagogic content knowledge is one who is capable of appropriately merging the mathematics content being taught with the relevant instructional approaches (Naidoo and Govender 2014). Technological pedagogical content knowledge epitomizes how a lecturer integrates technology based tools successfully within the educational milieu.

Shulman (1987) categorized the different kinds of professional knowledge that an effective teacher ought to possess (Van der Sandt and Nieuwoudt 2003) and aspects of these categories (Shulman 1987) were used to frame this paper. The categories include content knowledge, pedagogical knowledge and pedagogical content knowledge (Ball et al. 2008). Content knowledge is a teacher's knowledge about a subject, while pedagogical knowledge refers to a teacher's knowledge about techniques, processes and methods for teaching (Drijvers et al. 2010) and pedagogical content knowledge refers to a teacher's ability to transform subject matter (Brijlall 2014). This transformation is required for the effective teaching and learning through the use of multiple ways of adapting and representing the subject matter in order to elude student misconceptions (Koehler and Mishra 2009). Pedagogical content knowledge in mathematics requires the merging of mathematics content and pedagogy.

In addition, each lecturer's technological pedagogical and content knowledge (TPACK) was under focus. TPACK refers to a teacher's expertise in combining technology based tools to promote effective teaching and learning within a learning milieu (Koh and Sing 2011). It includes an understanding of how concepts may be efficiently illustrated through the use of technology and effective pedagogical strategies (Drijvers et al. 2010). Mishra and Koehler (2006) extended the work of Shulman (1987) to include technological and pedagogical content knowledge. A teacher's knowledge and ability to select appropriate tools is important for effectively integrating technology based teaching methods within the educational milieu (Mistretta 2005; Niess 2005; Brijlall 2014). Generally changes in pedagogy are often associated with teachers who want to try innovative approaches to teaching after participating in professional development activities (Bennison and Goos 2010). Thus, the assumption exists that for teachers to use technology as an effective tool, they ought to possess adequate TPACK.

MATERIAL AND METHODS

Ethical clearance was obtained from the research office of the participating university and additionally each participant was invited in writing to participate in the study. Each participant was provided with an informed consent form to peruse at their leisure moreover, participants were informed of their right to withdraw from the study without prejudice. Subsequently, each participant was also informed that they would be invited to a dissemination of results discussion session at the end of the study.

This was a qualitative case study located within an interpretive paradigm. Lecturers were asked to complete a questionnaire and they were interviewed. The questionnaire and interview

focused on each lecturer's use of technology based tools in their teaching. The semi-structured interview was used to gain an in-depth understanding of how technology was integrated within the mathematics educational milieus. Thus, through an in-depth and detailed examination, the six lecturers' teaching strategies were analyzed. Qualitative research was conducted to develop a descriptive understanding of what the lecturers' views pertaining to the use of technology were (Savenye and Robinson 2004). The interpretive paradigm was used because there was a need to describe and understand the subjective experiences of the participants. Qualitative data was collected during the 2013 and 2014 academic year.

Data Collection

The questionnaire was piloted with three randomly selected participants. After the reliability and validity of the questionnaire were verified through analyzing the responses, the amended questionnaire was distributed to the remaining nine participants for the main study. Subsequently, based on a qualitative analysis of each questionnaire, the final sample comprised six participants. The final sample included participants with a different number of years lecturing, different gender, different age groups, and different levels of qualification. Participants who alluded to using technology based teaching methods within their lecture room were purposively selected as part of this sample. There were four female and two male participants in the final sample. The participants for the main study are reflected in Table 1.

A semi-structured interview schedule was used to enable both the participant and researcher to engage with new ideas and thoughts during the interview as these ideas emerged. Each participant was interviewed after individual questionnaires were analyzed. The interviews were audio recorded (with the participants' permission) and then transcribed. The purpose of the interview was to probe responses to items on the questionnaire and to gain more clarity on each lecturer's views on the use of technology in the teaching of mathematics. Each interview lasted between 30 to 45 minutes. The interview began with a few general questions so as to place the participant at ease, and then progressed to specific questions based on individual responses on the questionnaire (for example, you indicated on your questionnaire that you use the Geometer's Sketchpad when teaching geometry, can you explain how you use this software program to teach problem solving in Geometry?).

RESULTS

This interpretive study employed the use of qualitative data analysis. Thematic coding and interpretive techniques were used to analyze the data. Based on an analysis of the questionnaires, some of the technology based tools that were used by participants were Moodle[3], the ELMO document camera[4], the Data projector[5], dynamic geometry software[6], the cellular phone and Internet downloads during lectures.

Additionally, from the analysis of the questionnaire it was established that each of the par-

Table 1: Main participants in study

Participant	*Number of years lecturing*	*Gender*	*Technology based teaching tool*
Avinash	11 - 20	Male	• Data projector • Moodle
Bongani	More than 20 years	Male	• Moodle • Dynamic Geometry Software
Kate	1 - 5	Female	• Data projector • Overhead projector • Internet
Lisa	More than 20 years	Female	• Elmo • Overhead projector
Mira	11 - 20	Female	• Data projector • Elmo • Internet
Nomsa	6 - 10	Female	• Data projector • Dynamic Geometry Software • Moodle

ticipants lectured within Higher Education for about 4 to 24 years. The participants were in the age group of 40 to 60 years. It was also evident that a percentage of the participants (42%) participated previously in workshops focusing on the use of technology within mathematics educational milieus. These workshops were part of their professional development training provided at the university at which they were based. Research (Bennison and Goos 2010) proposes that teachers often incorporate what they have acquired at professional development activities into their practice, which in turn leads to changes in student attitude and achievement.

Moreover, some participants (25%) indicated on the questionnaire that they were informally trained by colleagues on the use of technology based tools for teaching mathematics. This training revolved around the use of the Over Head Projector (OHP), data projector (DP) and the ELMO document camera. This finding exhibited that opportunities were provided for colleagues to share experiences and collaborate within their respective disciplines (Drijvers et al. 2010). Moreover, based on the data collected it was evident that all participants valued the use of technology in mathematics teaching within Higher Education and the majority (71%) articulated a desire for more technology related professional development activities. Research (Bennison and Goos 2010) supports this idea and adds that many teachers want to learn more about how to effectively integrate technology within their educational milieus with the aim of enhancing student learning. Furthermore, based on an analysis of each interview, four major themes emerged. The use of technology based methods assisted in saving time, alleviating learning challenges, making abstract concepts more accessible and providing easy access to information.

DISCUSSION

Saving Time

Based on the lecturer interviews it was apparent that the use of technology based teaching activities saved time during the lecture. By using computer programs to construct figures in mathematics prior to the lesson saves time during the lecture and these diagrams may also be used for lesson planning. For example, the participants believe that by planning lessons using dynamic geometry software and Microsoft PowerPoint presentations for mathematics saved time during the lesson.

Nomsa: *…geometry and trig become easier to teach using Sketchpad*[7]*…less time is spent drawing…explanations become easier to follow… students can immediately see changes on the diagram…*

Kate: *…using PowerPoint in the class is quicker…students can see complex concepts straight away and graphs and figures are clear…*

Lisa: *…using transparencies is efficient, since they [the transparencies]*[8] *are already prepared in advance…showing them [students] long complex solutions or diagrams becomes faster and easier…*

A significant percentage (58%) of the participants valued the use of technology in the lecture room because the use of technology based tools allowed them to teach the same content in new and interesting ways. The majority of these participants used technology based tools to teach graphs of functions and geometric proofs in mathematics. It was a common belief among the participants that technology adds more value to the lesson because the students, through the use of computer software were now seeing the evidence of the transformations in graphs of functions and geometry proofs and riders[9]. While research (Garofalo et al. 2000) supports this notion, it must be noted that technology is used only when students have acquired the appropriate mathematical and technological understanding.

While one has to concede that software programs in mathematics cannot do proofs of mathematics theorems for the user, it often provides empirical evidence and guidance. The use of software programs may be seen as a scaffold (Trouche 2004) for the effective teaching and learning of geometric proofs. The responsibility of proving however still lies with the user. In addition to teaching transformations in graphs and guiding students through proving theorems in mathematics, the participants also used technology to demonstrate concepts that students had not seen or been exposed to previously. This claim is evident in the comments that follow:

Mira: *…I often use video clips to teach math…*

Lisa: *…some students did not know what a prism was…I showed this using the ELMO…I used a Toblerone [Swiss chocolate] box…*

It was evident that the participants in the study knew their students and used this knowledge to reflect on and adapt their lessons to ensure maximum benefit of the learning process for their students. In order for the lecturers to succeed at this, they needed to have a good knowledge of the content being taught and they needed to know how to teach this content (pedagogic content knowledge) in order for the effective teaching and learning of mathematics to ensue. Based on the comments above, it was apparent that the participants were indeed agents of change (Ertmer and Ottenbreit-Leftwich 2010). They were changing how their students viewed and learned mathematics. These lecturers were exposing their students to new ideas and innovative strategies to help make mathematics more visible, interesting and fun. Being able to visualize and manipulate 3D objects is seen as an advantage for effective learning (Shallcross and Harrison 2007). Thus, these activities not only deepen the students' understanding of mathematics and its applications but also help make mathematical ideas and concepts more meaningful (Huang and Li 2009).

Alleviating Challenges

It was evident based on the interviews that the use of technology when teaching alleviated some of the barriers within the diverse educational milieus. Based on the interviews, English was often some of the students' second or third language. The teaching of abstract concepts in a language that is not the students' main language (Setati 2005, 2008) creates a challenge for any teacher. While students ought to possess sufficient language proficiency to ensure that their results are not affected by language problems still, language issues cannot be ignored. Teachers need to create ways to assist the student in grasping concepts within the diverse educational milieu.

Kate: *…sometimes when language is a problem I use the projector to show complex 3D shapes like prisms and pyramids…easier and avoids confusion…*

Avinash: *…I compile notes and diagrams to help students…it helps when I want to divide the class into groups…group work is labeled and presented…there are no misunderstandings students can refer to the slide regarding their task…*

Bongani: *…I show different type of examples using a presentations…it is quick… students know what I mean…they can see the presentation immediately and compare the different types of methods used to solve…they are all on the same level…they know what I am talking about…even when we talk about new examples…they can refer to the methods on the screen and discuss with each other…*

Avinash: *…I started working on an electronic math dictionary…words in English don't mean the same as words in math. For example: figure, volume, table…it's difficult for them [students] to understand…they can look up what it means when working on math problem…the dictionary is projected during lecture…very helpful for abstract concepts as well…*

If the language of instruction is not the student's first language, this disadvantages students greatly within a learning environment. Thus, alleviating the challenges and barriers to learning are important for promoting effective teaching and learning. As is evident from the above excerpts, the participants were of the opinion that the use of technology within the educational milieu removed some of these challenges. The participants acknowledged that every year their class became more diverse and they were compelled to reflect on and evaluate their teaching methods. In some cases their lesson plans changed while they were teaching.

Mira: *…I use ELMO to show constructions… I can also refer students to specific sections in the module outline or course notes…this is often done on reflection while in the lecture…I connect with my students immediately if there is a problem…ELMO helps me especially when I need to change my teaching on the spur of the moment…*

Based on the excerpt above, it is evident that new technologies are emerging and are making a significant impact in Higher Education (Mosenson and Johnson 2008; von Konsky et al. 2014).

Bongani: *…I used Sketchpad…but as I taught, I noticed that not all students in the class could work on the computer…it was the first time for them…I realized I needed to change my strategy…I then worked on the board…only when they [students] knew what was expected…I moved back to the computer…*

Reflection is an important skill for a teacher's professional development since this skill assists in justifying the way one teaches, the resources that one uses and the cultures that one creates within an educational milieu (Ollerton 2009). Similarly, Danielson (1996, 2012) maintains that reflecting and analyzing on one's teaching is an important professional responsibility for a teacher. Moreover, demonstrating flexibility and responsiveness by changing in action with respect to methods is a sign of a proficient teacher (Danielson 2007).

Additionally, by using technology, lecturers did not need to print copious notes, and this assisted in saving paper and printing costs.

Avinash: *…I use Moodle to send readings and tasks to my classes… I don't have to make multiple copies of notes…this is my small way of saving…*

Bongani: *… I send them tasks immediately after lecture…no need to wait for material to be run out…saves energy and the environment…*

As is evident, lecturers rely on the use of Moodle to upload readings, assignments and past assessments for students to work on. Thus, it was apparent based on the above interview transcripts, that integrating technology within the teaching of mathematics at Higher Education Institutes saved paper and therefore protects the environment.

Making Abstract Concepts More Accessible

The participants were of the opinion that the use of technology based instructional tools supported them in making abstract mathematics concepts easier to understand. Complex concepts like solving the slope of graphs, limits of function, working with problems in differential calculus become easier to teach through the use of technology based teaching tools. These technology based teaching tools included the graphical calculator, computer software programs and Elmo/Moodle.

Mira: *…resources should be used as a means to enhance the lecture, for example providing visuals to concepts that are microscopic and difficult to explain, videos that emphasize a concept or PowerPoint presentations to large groups of students are unable to see writing on…board…*

Nomsa: *…Sketchpad is wonderful…they can just type in a graph and it appears…they can then identify what happens when the period or amplitude is changed…it is not abstract anymore…*

In addition, participants believed that students ought to practice more examples and exercises in order to make complex concepts easier to understand, one way of ensuring this was to place additional or extra credit exercises on Moodle, where students could access them and work with them for extra marks.

Bongani: *…I want students to be take charge of their learning…I place extra credit tasks on Moodle… students can work on them and practice more examples…they can email me with queries…in this way they become independent and responsible for their learning…*

Nomsa: *…extension tasks are placed on Moodle…they [students] work on them…if they need help I can assist immediately online…*

Avinash: *… Moodle is easily accessible… they [students] can work anytime on the practice exercises…they don't need to come to class for help…they can ask their peers for help or even request help from me via Moodle… it is practical and efficient way…*

It is important to share effective ways to prepare prospective teachers to be able to incorporate technology into their future educational milieus (Mistretta 2005). The teaching methods reflected in the excerpts above are instrumental in establishing a culture of learning whereby students are engaged in learning, these are important aspects of becoming a proficient teacher (Danielson 1996, 2007). The use of technology based teaching tools assists students in developing important skills, for example effective communication, analyzing and interpreting data, understanding simulations, managing tasks, and problem solving (Mosenson and Johnson 2008). The value of integrating technology within the educational milieu through the use of examples and demonstrations ought to be encouraged (Mosenson and Johnson 2008).

Teachers ought to be at the forefront of new technology and technology based teaching methods (Mosenson and Johnson 2008; Louw 2010), to reach this goal, teachers need to develop themselves professionally. Teachers ought to become lifelong students and be instrumental in equipping and empowering themselves (Louw 2010).

Providing Easy Access to Information

Additionally, the participants agreed that access to information and research became easier through the use of technology. Frequently during the lecture, certain concepts and terminology were mentioned that needed further clarification. Through the use of search engines and the Internet, the lecturer could easily download the latest updated information for clarification purposes. This is supported by research, which indicates that the appropriate use of technology provides ready access to real data and information (Garofalo et al. 2000).

Kate: ...*sometimes students ask about concepts that are difficult to show on the board… I quickly download information there and then and they [students] can see the projected information…the Internet is fast and easy…*

Mira: … *I don't worry too much about not having enough problems to give them [students]…especially when we are working with real world problems… I can always download extra problems from various free websites…it is easy…*

It was evident here that technology was necessary in the teaching and learning of mathematics (Garofalo et al. 2000) and the integration of technology in teaching transformed the way that the lecturers taught, which in turn brought about changed educational milieus (Watson 2001; von Konsky et al. 2014). This is supported further by the interview transcripts that follow.

Avinash: … *they [the students] send messages on Moodle to the class…we can talk about issues or clarify…so before they [the students] get to class we iron out problems… I don't think I know of an easier way…so it is sort of blended teaching and learning…it is another way of teaching…as I said earlier… I send notes and information through Moodle…they [the students] can access information for the lecture anywhere…*

Bongani: …*it [Moodle] helps students be more independent…it changes how I teach…feedback is given immediately…they can access the feedback anywhere and at any time…they [the students] don't have to wait to meet me…in a sense the consultations are done online…*

As can be seen, integrating technology within the educational milieus was used for different purposes but the aim was to enhance and support student learning.

CONCLUSION

The use of technology related pedagogies within mathematics education is essential to cope with the influx of technology savvy students. Lecturers ought to be aware of what technology is being used and how they are being used within the different educational milieus. In this paper the results of a qualitative, interpretive study has been reported on. The paper sought to answer the following question: What technology based tools are being used by mathematics lecturers within higher education? Based on the data gathered it was evident that the participants used technology based tools like Moodle, dynamic geometry software, the data projector, the Internet, the overhead projector and Elmo, while teaching mathematics. It was apparent from the data collected that all participants valued the use of technology in mathematics teaching within Higher Education and many (71%) expressed a desire for additional technology related professional development activities.

Reasons provided for this included,

1. The use of technology based methods assisted in saving time during the lecture and during lecture preparation.
2. The use of technology based tools alleviated learning challenges particularly when the educational milieu catered for students from diverse backgrounds.
3. Technology based tools assisted in making abstract concepts more accessible primarily when students were asked to work with complex problem solving tasks involving 3D objects.
4. Technology related pedagogies provided easy access to information both during the lecture and before or after the lecture.

RECOMMENDATIONS FOR FUTURE STUDIES

The conclusions of this paper while not generalizable indicate that technology related pedagogies benefitted both the mathematics lecturers and students. The researcher suggests that technology related pedagogies be shared with mathematics lecturers at other institutions. One way of doing this is to share effective teaching

practices at conferences and seminars. Furthermore, mathematics lecturers at other institutions ought to explore what technology related pedagogies are being used currently at their own institutions for future sharing and presenting at conferences and seminars. A possible way of doing this is by encouraging Discipline Heads at various tertiary institutions to initiate discussions within their disciplines revolving around innovative and effective pedagogies. The sharing of good practice may enhance mathematics lecturers teaching strategies, which in turn may improve the students' understanding and performance in mathematics.

ACKNOWLEDGEMENTS

The researcher would like to thank the University of KwaZulu-Natal for partially funding this paper (TLCRG). The opinions expressed here are those of the researcher, and do not necessarily reflect the position, policies or endorsements of the university.

NOTES

1. The words teacher and lecturer are used synonymously in this paper.
2. The terms teaching and lecturing are used synonymously in this paper.
3. Moodle is an Open Source Course Management System (CMS) used at the participating university. Moodle is license free Open Source software. It allows lecturers, trainers and administrators to manage online learning and online training.
4. An ELMO document camera also known as a visualizer is a teaching tool, which allows teachers to display anything from a coin, diagrams, pictures or even a person in a room in color. You can point, annotate, zoom in and out, or get different views by turning the camera head of the document camera.
5. A device that projects computer output onto a screen or wall. It is used in classrooms and auditoriums for instruction and power point presentations.
6. Dynamic geometry software is used for teaching geometry in a discovery mode. Learners are encouraged to use computer software (such as Geometer's Sketchpad or Geogebra) to construct figures that can be altered by dragging points around the computer screen while the underlying relationships are unchanged.
7. A type of dynamic geometry software that may be used for teaching geometry in the classroom.
8. The words in square brackets have been added by the researcher to assist the reader in understanding the transcript excerpts.
9. Geometry riders refer to mathematics problems that are based on geometric proofs.

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