**Integrating Classroom Technology: South African Mathematics Teachers**

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**Declaration of Interest Statement**

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## Abstract

Studies have shown that when mathematics teachers integrate technology in their classrooms, the applications tend to be routine rather than transformational. Since limited research has been undertaken on integrating technology in teaching mathematics in developing countries, this study investigates which technologies South African teachers are integrating in their classrooms and how. This quantitative study showed that, although the most commonly used technology was a laptop/ computer, the use of data projectors as teaching aids was most effective. Further investigation indicated that 72% of participants used a data projector as a substitute for the chalkboard or overhead projector and did not change their teaching when integrating technology. This study found that it is important to create professional development programs that focus on training teachers to make fundamental pedagogical shifts when integrating technology in their classrooms.

**Keywords:** education; technology integration; SAMR; mathematics education

## Introduction

### *Background*

Lim et al. (2013) note that the expectation of educational transformation drives investments made by governments and other entities to provide information and communication technologies (ICTs) for use in schools. However, citing international research, they conclude that transformation has not occurred on the anticipated scale and that, like many previous innovations, ICT has barely affected the practice of most teachers. Many countries have introduced policies or initiatives to improve learner achievement through the use of technology. For clarification, the term *technology* will be used in this study to refer to both hardware and software utilised by mathematics teachers for teaching and learning this subject. The use of ICTs in education is promoted by the United Nations (UN) in its 2030 Agenda for Sustainable Development (UN General Assembly, 2015). In a very broad sense, this type of sustainable development aims to improve the state of nations and the world itself. The Sustainable Development Goals (SDGs) are viewed as a type of roadmap to achieving a better and more sustainable future for all by addressing the global challenges humanity faces. The fourth goal, SDG4, deals with education and aims to "develop education systems that foster quality inclusive education and promotes lifelong learning opportunities for all" (UNESCO, 2017, p. 7). More specifically, it encourages using ICTs for improving access to inclusive and equitable education and providing a good quality of education for all. The type of education referred to in SDG4 must seek to match the needs of 21st-century learners.

## Literature review of related work

### *Initiatives taken to enhance technology integration in schools*

Some initiatives taken across the globe include, for example, the USA state of Pennsylvania that spent vast amounts to introduce the 1:1 technology initiative at the secondary level (Wojcik, 2015). The name of this initiative refers to the ratio of laptops to students as every student was provided with a laptop. It is important to note that significant investments in technology education are not being made only in highly developed countries, such as the United States or South Korea, but also in developing countries. eLearning Jamaica, for example, has a mandate to integrate technology in education (Angus, 2018). Rwanda has introduced a smart classroom initiative to equip schools with computers and access to the internet to promote the integration of ICT in the classroom (Karuhanga, 2018). In India, more than 6 000 secondary government schools are being provided with high-tech laboratories under a centrally sponsored ICT scheme (Trucano, 2019). These are but some examples of ICT integration initiatives around the world.

In this study, the focus was on the integration of ICTs in South Africa. Following the international trend, the South African government introduced a policy to use technology to change teacher pedagogy and improve learner achievement (DBE, 2004), known as the e-Education White Paper. This policy identifies six strategic objectives for action, including reference to the integration of ICTs in teaching and learning. To drive the government's desire to develop digital or smart classrooms, the Gauteng Department of Education (GDE) announced a R17 billion investment in a paperless classroom initiative (Monama, 2016). With pilot phases well underway, the GDE invested in excess of R800 million in the 2015/16 financial year (GDE, 2015). In the 2016/17 financial year, the GDE allocated a further R1 billion to the transformative *ICT in Education* initiative (GDE, 2016). In the 2017/18 and 2018/19 financial year, the GDE allocated a further R274 million (GDE, 2017) and R238 million (GDE, 2018) for the continued roll-out of e-Learning strategy. In the 2019/20 financial year, the GDE allocated R815 million for e-learning devices and e-LTSM with the aim of transforming township schools into functional ICT-enabled learning spaces (GDE, 2019). Not only in Gauteng, which is one of the nine provinces of South Africa, but nationally, South Africa has initiatives in place to equip schools with devices, connectivity, digital content and ICT integration training for teachers (DBE, 2020). However, Atabek (2019) states that technology integration in education still encounters obstacles despite the significant investment. Other studies even show that, despite the considerable investment in technology, no significant impact can be observed from using these technologies in the classroom. One example of this is the study by Gui et al. (2018), who investigated the impact of different types of digital technologies on the learning outcomes in Italian lower secondary schools over a four-year impact. Gui et al. (2018) concluded that, at a national level, no significant impact emerged for any of the three technologies (interactive whiteboards, Wi-Fi connection and mobile devices) considered. Comi et al. (2017) caution against massive investments in equipping teachers and schools with technology, especially if it is not accompanied by investment in teacher training. Considering the large investment made by the South African government in providing schools with ICTs, it was necessary to determine how South African teachers are integrating technology in their classrooms.

### *Utilising technology within the teaching and learning environment*

How technology is integrated can vary according to grade, type of school, availability of equipment, curriculum guidelines, teacher knowledge and administrative freedom to explore, and therefore fluctuates from classroom to classroom. During the past decade, researchers and educators have developed several standards, frameworks, models and theories to guide the integration of technology in the educational domain (Hamilton et al., 2016). According to Mishra and Koehler (2006), no single framework exists that can provide all the answers or sketch the complete picture. Over the years, the word technology has been defined and redefined from various perspectives. Draper (2011) states that the terms information technology (IT), computer technology and technology are regularly used interchangeably and may refer to the same thing.

***Prevalence of ICT integration in education***

Although the integration of technology in education now demands increased investment by most governments, the adoption and integration of technology in the education sector are still far from the desired level (Buabeng-Andoh, 2012b). Literature suggests that, despite its potential, the introduction of technology into the education system has not brought about the expected progress (Ertmer & Ottenbreit-Leftwich, 2010; Iqbal, 2017; Whitworth, 2012). According to Tezci (2011), the advances made concerning equipping teachers with knowledge of the use of technology and the value of integrating it in the classroom, most teachers still do not effectively integrate technology in their classroom practice. This opinion was supported by the findings of Rains (2018), who reported that teachers still face challenges in adapting their teaching to integrate new technologies.

The DBE estimates that only 26% of South African teachers have basic technology skills, with only 7% functioning at an intermediate competency level (Alfreds, 2016). There has been no radical improvement in the situation since 2009 when Howie and Blignaut (2009) found that only 18% of Grade 8 mathematics teachers used technologies in teaching and learning activities, and that technology was used mainly for administration and monitoring learners' feedback. According to recent and previous Trends in International Mathematics and Science Study (TIMSS) reports, achievement in mathematics in South African schools is among the worst in the world (Reddy et al., 2012; 2016; Human Sciences Research Council [HSRC], 2020). Therefore, it is essential to undertake research to determine which technologies should be integrated and how they can be effectively utilised to improve the standard of mathematics education. The 'Action Plan 2019' document echoes this and further states: 'The area is a difficult one because the evidence is not very clear on, for instance, what technology investments are best for improving learning and teaching' (DBE, 2015, p. 14).

Although many South African mathematics teachers have access to technology in their classrooms, they often refrain from using it. The South African DBE states that 'there is still a major weakness in the system when it comes to the implementation of ICT to improve the teaching and learning process' (DBE, 2015, p. 14).

### *A framework for technology integration in the classroom*

To effectively address the research questions, the Substitution, Augmentation, Modification and Redefinition (SAMR) Model (Puetendura, 2010) was utilised. This model follows a four-level approach to selecting technology for use, the evaluation of technology use in a classroom setting, and classifies the use of technology into four categories, namely Substitution, Augmentation, Modification and Redefinition (see Figure 1) (Puentedura, 2006).

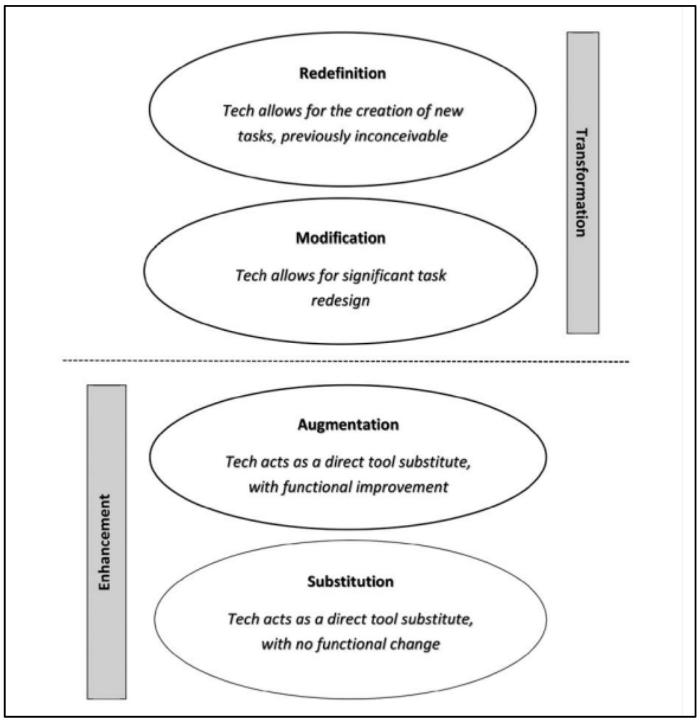


**Figure 1:** Puetendura (2010). A brief introduction to TPCK and SAMR

The SAMR Model provides a tool for assessing and evaluating the impact of technology practices in a traditional classroom setting (Hos-McGrane, 2014; Lund, 2015; Myers, 2014; Puentedura, 2012; Tucker, 2013). Considering the type of data generated from the questionnaire, this model was therefore perceived to be the best suited to this study.

*Substitution:* According to Puentedura (2014), in the category Substitution, digital technology is substituted for analogue technology, but the substitution produces no functional change. Jude et al. (2014) assert that in this category, a computer is used simply to replace a typewriter to produce documents without any substantial change to their functions.

*Augmentation:* Puentedura (2014) explains that in the category Augmentation, digital technology is substituted for analogue technology, and the substitution produces 'some functional improvements'. According to Fabian and MacLean (2014), although the same things are done in the teaching and learning environment, the introduction of technology does result in minor improvements. Technology, therefore, acts as a direct tool; in other words, it acts as a substitute and its use results in functional improvements in teaching and learning practices. Based on the example provided by Jude et al. (2014), under the category Augmentation, a computer can be used to replace a typewriter and offers a substantial increase in functionality, such as the cut-and-paste and spell-checking functions.

*Modification:* Under the category Modification, technology allows significant task redesign (Puentedura, 2014). According to Lund (2015), this category allows for considerable changes in the nature of a task and its redesign to achieve a potentially different, deeper outcome. Using the writing examples from the previous two levels, the teacher can integrate Web 2.0 tools, such as blogs and wikis, into a lesson (Lund, 2015).

*Redefinition:* Redefinition allows for the creation of previously inconceivable new tasks, a remix and redesign process, a total transformation of one's practice (Fabian and MacLean, 2014). According to Kihoza et al. (2016), the redefinition level is achieved when technology is used to create novel tasks. Referring to the writing example used in the previous three levels, Lund (2015) explains that learners could be asked to use widely available technology to convert their written assignments to multimedia audio or video projects at the redefinition level. Coming back to the teaching and learning of mathematics, in the category Redefinition, it is worth mentioning the Mathematical Teaching and Learning Framework for South Africa, released by the DBE in 2018, that emphasises the total transformation of one's practice. This framework was not intended to be a new curriculum, but rather a framework model for teachers to transform their mathematics teaching; "[t]his transformation should lead to teaching for understanding, so that learning for understanding will take place in all mathematics classrooms in South Africa" (DBE, 2018, p. 10). The framework includes many conceptual uses of dynamic geometry software in the teaching of high school geometry (see, for example, DBE, 2018, p. 75). The non-conceptual use of digital technology has been a concern for a few decades now and, to address this concern, Maddux (1984) introduced the notion of Type I and Type II educational technology applications. Type I applications of technology simply make it quicker, easier, and more convenient to continue teaching in traditional ways, whereas Type II applications employ user interaction and make new and better ways of teaching and learning available that is only practical with technology. Since 1984, the conceptual use of digital technology has been expanded on by various authors (Maddux, 1987; Maddux & Cummings, 1986; Maddux & Johnson, 2005a, 2005b). Type II applications of technology in education have been highlighted as a topic of such importance that the journal, *Computers in the Schools*, have published special issues on this topic (Abramovich, 2013; Maddux & Johnson, 2005c).

***Purpose of this study***

This research aimed to gain deeper insight into which available technology South African mathematics teachers view as having the most significant impact on the teaching and learning of mathematics. It further aimed to gain deeper insight into which ICTs are being integrated by South African mathematics teachers and how integration takes place. The present study further aimed to explore to which extent males and females differ in ICT view, use and integration as there are many studies on this topic with different (contradictory) findings (Gebhardt et al., 2019; Punter et al., 2017). This led to the first research hypothesis of the present study: it is expected that male and female teachers differ significantly in how they view, use, and integrate ICT in their teaching. The present study also aimed to explore to which extent younger and older participants differ in ICT view, use and integration as there are many studies on this topic; for example, the study by Korpinen et al. (2014) showed that younger persons used and integrated ICT significantly more than older persons. This led to the second research hypothesis of the present study: it is expected that younger and older teachers differ significantly in how they view, use, and integrate ICT in their teaching.

**Research questions for this study**

The following four research questions (RQs) were formulated for this study:
RQ1: What available technology do mathematics teachers view as having the most significant impact on the teaching and learning of mathematics?
RQ2: How is technology being integrated in the teaching and learning process?
RQ3: Are the significant differences in how males and females view, integrate and use technology in the teaching and learning process?
RQ4: Are the significant differences in how younger and older teachers view, integrate and use technology in the teaching and learning process?

## Methodology

### *Research Design*

A quantitative post-positivist research design was used. Post-positive research assumes that scientific reasoning and common-sense reasoning are, in essence, the same thing. Post-positivism suggests that a reality exists but that we can know reality only imperfectly due to our own human limitations, including subjectivity (Mertens, 2014). Post-positivist researchers acknowledge that individuals cannot be held to the rigorous measurements of the positivist approach (Mertens, 2014). Furthermore, Mertens (2014) also assert that the post-positivists accept that the information stated by the individual is significant but is not necessarily generalisable to others.

### *Participants*

Participants in this study were 191 in-service mathematics teachers. The majority of the participants were female (79.10%), and the average age of the participants is 42.14 years (standard deviation = 13.96). The majority of participants (89.50%) taught in public schools (see Figure 2(a)), and most had taught mathematics at secondary schools during the five years before this study (see Figures 2(c) and (d)). It should be noted that although an attempt was made to distribute the e-survey across all nine provinces of South Africa, most of the respondents taught in urban (68.06%) schools (see Figure 2(b)) where ICTs are readily available, and mainly in Gauteng (45.03%) and the Western Cape (21.47%), since both these provinces focus intensively on ICT and have implemented various ICT plans.

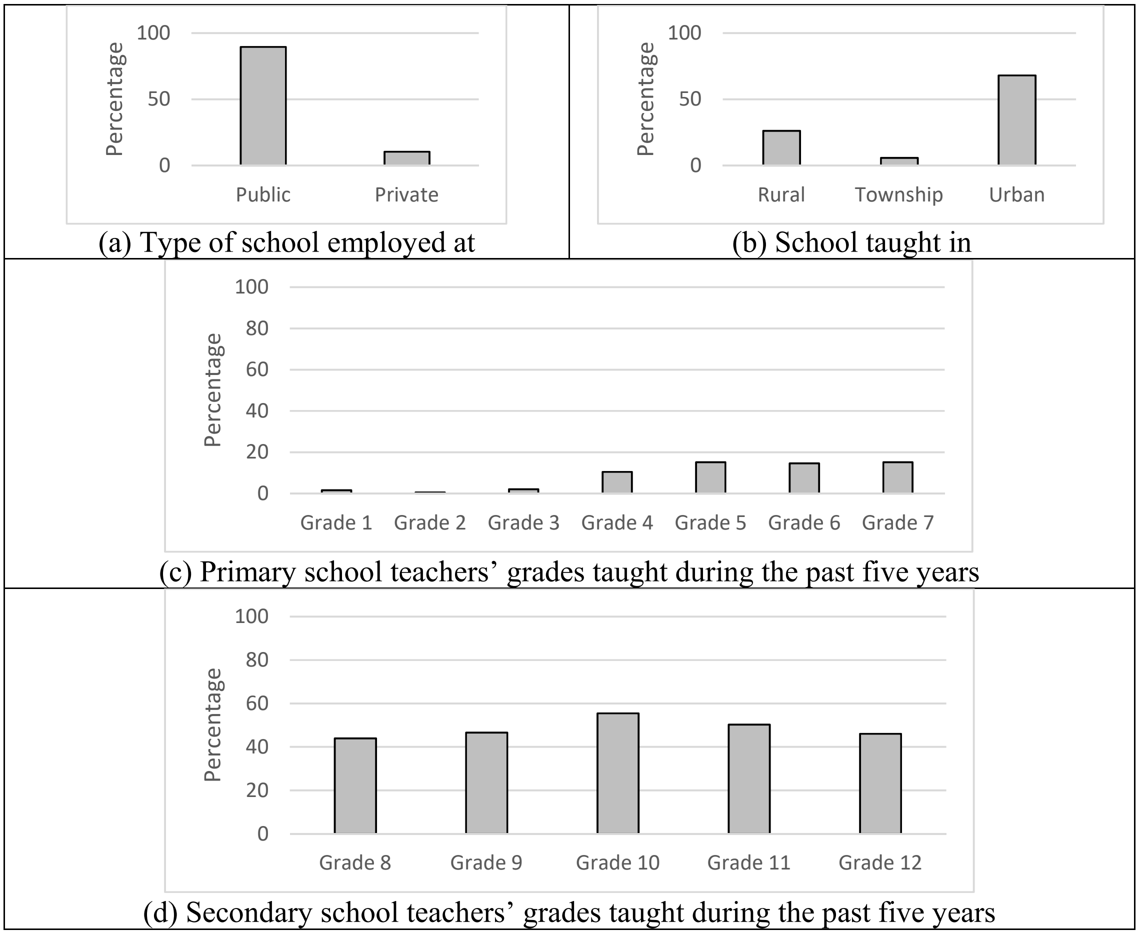

**Figure 2**: Demographic information of participants regarding type of school and grades taught in

***Procedures***

Purposive and convenience sampling methods were employed to identify and select participants. Purposive sampling is a selective type of non-probability sampling during which participants are selected based on certain traits and expert knowledge (Etikan et al., 2016). In this case, participants had to be in-service mathematics teachers. The convenience sampling technique, a non-probability sampling technique (Etikan et al., 2016), was chosen as the researchers had convenient access to a group of in-service teachers who teach mathematics. The majority of the group, that the researchers conveniently had access to, was members of the "*Vereniging vir Afrikaanse Wiskunde-onderwysers*", which is a South African mathematics association with predominantly Afrikaans content and following. For this reason, the questionnaire was made available in both Afrikaans and English, with the majority of the respondents (84.81%) completing the Afrikaans version. Several provincial Department of Basic Education Mathematics coordinators agreed to distribute the online questionnaire to mathematics teachers in their clusters to recruit participants. The School Support Centre, a non-profit organisation that prides itself on rendering a range of quality services, including worksheets, lesson plans, short professional development courses and two annual conferences to its members (mostly Afrikaans-speaking, in-service mathematics teachers), also voluntarily distributed the online questionnaire to its entire membership of approximately 1 000 in-service mathematics teachers. The Faculty Research Ethical Committee approved the questionnaire. The research met the ethical guidelines set out by the University, including confidentiality, voluntary participation, informed consent, anonymity, trust, and safety in participation. A total of 191 valid questionnaires were collected. All responses were entered into MS Excel and then imported into the Statistical Package for the Social Sciences (SPSS) version 26 for statistical analysis. It should be noted that although age is a continuous variable, for comparison purposes, two groups were created, namely, 'younger than 40 years' (45.0% of the participants) and '40 years of older' (55.0% of the participants).

### *Instrument and measurements*

An online questionnaire was distributed to obtain as large a response as possible. The questionnaire consisted of five sections: Section A captured the demographical data of the respondents; Section B focused on the different types of ICTs accessible to respondents; Section C was based on the UTAUT framework and investigated the reasons why respondents were using ICT in the teaching and learning environment; Section D was based on the SAMR model and attempted to gain a deeper understanding of how the respondents integrated ICTs; and Section E was designed to capture the respondents' intention to use ICT as opposed to their actual use of ICT. This article focuses on Sections A, B and D of the questionnaire; the findings of the other sections are reported in [*Surnames removed to ensure anonymity of authors*] (2020).

The validity of the questionnaire was checked by computing Cronbach Alpha values, and since all the Cronbach Alpha values were above 0.7, the questionnaire was deemed to be reliable (Field, 2018). The study was quantitative as questionnaires were distributed, and there were no in-depth interviews or reflections. The highly structured questionnaire consisted of mainly closed-ended questions.

## Limitations

Although the questionnaire was distributed to approximately 1 000 in-service teachers, only 191 responded. This affected the generalisability of the study, which is dependent on large representative populations. Another limitation was the fact that non-probability sampling techniques are limited by the subjective nature of selection. Since the selection of participants was based on expert knowledge and convenience, the sample was not representative of the entire population, and, accordingly, inferential statistics could not be deduced and generalizability to a greater extent is not possible.

## Data analysis and results

### *Research Question 1*

To address RQ1 about what available technology mathematics teachers view as having the most significant impact on the teaching and learning of mathematics, participants were asked to list the technologies they felt had the most significant impact on the teaching and learning of mathematics. This was an open-ended question, and many responses included more than one technology as technologies often work in combination with each other. For instance, participants would list a data projector, a personal computer and MS PowerPoint. A total of 278 technologies were identified, and by employing content analysis these technologies were later categorised into twenty categories. Table 1 provides a summary of the categories identified and the corresponding frequencies.

**Table 1.** Summary of the identified categories

| Technology | Frequency | Percentage |
|---|---|---|
| Data projector | 54 | 19.42% |
| Dynamic mathematics software | 53 | 19.06% |
| Interactive whiteboard | 46 | 16.55% |
| Online video-streaming services (YouTube) | 24 | 8.63% |
| Personal computer / laptop | 20 | 7.19% |
| MS Office (Word, Excel, PowerPoint) | 20 | 7.19% |
| The internet | 17 | 6.12% |
| Document camera / Visualiser | 14 | 5.04% |
| Tablet, cell phone and applications | 11 | 3.96% |
| Television | 4 | 1.44% |
| Whiteboard / Chalkboard | 3 | 1.08% |
| Printer | 2 | 0.72% |
| Overhead projector | 2 | 0.72% |
| Online feedback software (Google forms and Kahoot) | 2 | 0.72% |
| Learner management systems (Edmodo and Moodle) | 1 | 0.36% |
| Video creation software (Explain Everything) | 1 | 0.36% |
| Cloud storage (Google Drive, Dropbox, MS OneDrive) | 1 | 0.36% |
| Scanner | 1 | 0.36% |
| Casio Emulator | 1 | 0.36% |
| E-books | 1 | 0.36% |

The technology perceived by 19.42% of the participants to have the most significant impact on the teaching and learning of mathematics was a data projector. This was followed by dynamic mathematics software, for example, GeoGebra, Desmos and Autograph, indicated for their significant impact by 19.06% of the respondents. This was not surprising as recent studies show that the use of dynamic mathematics software in the classroom improves student achievement (Singh, 2018). The effect of using interactive whiteboards was indicated as having the strongest impact by 16.55% of the respondents, which placed it in the third position. Although data projectors are normally used in conjunction with interactive whiteboards, it should be noted that many interactive whiteboards have built-in data projectors and are often perceived by teachers as a single teaching aid. If interactive whiteboards are regarded by so many researchers as a valuable teaching tool in South African classrooms (Mihai, 2020; Mokoena et al., 2019; van Niekerk, 2015), one can only wonder why it is used by only just more than 15% of teachers.

The availability of interactive whiteboards does, of course, play a role, and interested readers are referred to the information provided by Saville et al. (2014) and Mokoena et al. (2019) on why the potential of interactive whiteboards has not been realised.

***Research Question 2***

To address RQ2 about how the technology is being integrated in the teaching and learning process, the participants first had to indicate what technology was available to them and, following this, participants had to indicate whether the technology was most frequently used in class for teaching, or most frequently used for preparation or most frequently used for personal development. Table 2 provides a brief summary of the top ten technologies identified. Only the top ten in each category will be reported on in this study.

**Table 2:** Summary of the top ten technologies identified

| Order | Availability of technologies | Technologies most frequently used in class for teaching | Technologies most frequently used for preparation | Technologies most frequently used for personal development |
|---|---|---|---|---|
| 1 | Personal computer / Laptop | Personal computer / Laptop | Personal computer / Laptop | Personal computer / Laptop |
| 2 | MS Word | Data projector | MS Word | The internet |
| 3 | Email | MS Word | Printer | MS Word |
| 4 | Printer | MS PowerPoint | The internet | MS Excel |
| 5 | The internet | Printer | MS Excel | Printer |
| 6 | MS PowerPoint | Interactive board | MS PowerPoint | Email |
| 7 | MS Excel | The internet | Scanner | YouTube videos |
| 8 | Data projector | MS Excel | YouTube videos | MS PowerPoint |
| 9 | Scanner | YouTube videos | Data Projector | Mobile devices |
| 10 | YouTube videos | Dynamic mathematics software | Dynamic mathematics software | Dynamic mathematics software |

In Section D of the questionnaire, the participants were also asked to elaborate on their answers relating to Table 2 by explaining how they applied the specific technology in the teaching and learning of mathematics. Content analysis was again used to make sense of the open-ended responses, and the data was coded by using predefined words and phrases linked to technology and education. For the longer question, which asked teachers to describe how they used specific technologies, a total of 203 responses were captured as some teachers mentioned more than one kind of technology. Only 159 of the 203 responses were deemed usable for analysis according to the SAMR Model, which provides a tool for assessing and evaluating how technology practices affect a traditional classroom setting (Hos-McGrane, 2014; Lund, 2015; Myers, 2014; Puentedura, 2012; Tucker, 2013); therefore, only replies that specifically indicated how the technologies in question were applied in the classroom environment were coded. Replies such as 'use it every day' and 'for introduction' were not coded, while replies such as 'use a computer to plan lesson' and 'YouTube or videos shown to learners' were coded. The data collected produced the results that are discussed below under the SAMR Model categories.

In the category Substitution, technology acts as a direct tool or a substitute and does not cause any functional change in the teaching and learning practices (Nkonki & Ntlabathi, 2016). It was evident from the data that the technologies listed in Table 2 were applied mainly as substitutes for the old ways of doing things. The content analysis showed that 71.70% of the responses contained words or phrases that included the following:

- *PowerPoint and PowerPoint with text and images*
- *Visual presentation of the mathematics*
- *Data projector with PowerPoint*
- *I use GeoGebra to show learners' graphs.*
- *I use a computer to plan lesson.*
- *I use an interactive whiteboard for all my lessons.*
- *YouTube or other videos are shown to learners.*
- *Drafting exam papers and capturing learner data*
- *Visualiser with a data projector used for illustration*

Further analysis provided explicit examples of how teachers integrated technologies. For example, participants used a data projector in combination with an interactive whiteboard, a document camera or a personal computer (using MS PowerPoint) to display typed lessons that appeared as if they had been written on a traditional chalkboard or whiteboard. The following excerpts did not suggest any functional changes in the teaching and learning methods and tasks:

- *'Show all workings step by step for learners while I can track learners' reactions and so they can see exactly how, for example, a protractor works.'*
- *'I use it (interactive whiteboard and data projector) throughout the period for writing, examples and graphs.'*
- *'I do the problems with the learners, sometimes using one of their books to show how marks are allocated in examinations. I illustrate how the calculator works visually and I show a memorandum of the homework whilst walking through the class and checking for homework.'*
- *'I use the package (MS Office) to type my documents, class lists, etc. I also use PowerPoint to show certain concepts.'*

Some participants mentioned that they used videos during their lessons. The use of online streaming services, such as YouTube, was rated to be the fourth most important with regard to its impact on lessons. This confirms that although online videos are useful in classrooms, they are merely substitutions for the teacher talking and explaining mathematical concepts. The following excerpts, taken verbatim from the data, support this finding:

- *'Start the lesson with YouTube video and then fill it up.'*
- *'The time factor for composing lessons is missing, therefore I use DVDs and YouTube.'*
- *'Quickly get a YouTube video to, for instance, illustrate the relationship between the volume of cube and pyramid or the application of data when the basics were covered.'*

The findings based on the content analyses indicate that Substitution was the largest of the four categories, with the majority of entries (57.59%) falling within this category. Although, as previously stated, the SAMR Model was applied to study the use of technology in higher education (Romrell et al., 2014), it is not well represented in current literature (Hamilton et al., 2016). An extensive review of the relevant literature failed to produce specific evidence of the application of the SAMR Model in mathematics education in South Africa. The findings of one study that focused on the adoption of the SAMR Model for the assessment of the use of technology in pedagogical adoption at university level concurred with the findings of this study. The findings of Jude et al. (2014) indicate that the most commonly applied category was Substitution, as 74.4% of the lecturers used technology to prepare lecture notes, assignments and examinations. This finding corresponds with the finding of this study, according to which personal computers / laptops were the most extensively used technology (84.6%) for teaching and learning. Furthermore, according to Jude et al. (2014), 48.5% of lecturers used LCD projectors to present their lectures. This study also found that many of the participating teachers used technologies to present information.

In the case of Augmentation, technology is used to do the same things with minor improvements (Fabian & MacLean, 2014). For example, instead of using MS PowerPoint or YouTube videos to present and explain mathematical problems, teachers use dynamic mathematics software such as GeoGebra, Desmos and Autograph to show how the variables of a function act on its graph. Although this could be illustrated by drawing numerous sketches on a traditional chalkboard or whiteboard, the use of technology enables teachers to do this with greater efficiency. Several responses attested to the integration of dynamic mathematics software as part of mathematics lessons:

- *'Autograph or GeoGebra makes calculus so visual, kids understand the whole tangent to the circle idea as they see how that tangent moves across the graph.'*
- *'Interactive sketches on mathsisfun.com (website) to illustrate the relationship with quadrants and graphs in trigonometry'*
- *'GeoGebra to show the differences of parameters. Slides that are applied to the basic concepts. The use of scanner projector for the textbook reference, etc. There are so many.'*

The following two extracts from the data clearly indicate that some teachers were functioning at the Augmentation level.

- *'What I write is being projected. I can work and use highlights and colours and it saves time not to erase boards and I can electronically make my lesson available to students.'*
- *'Share my prepared notes with my learners via Shareit, explain most geometric figures with ease.'*

Overall, the content analyses indicated that 23.90% of the participants were using technologies at this level. Several technologies provide minor improvements; however, this does not necessarily translate to more learner interaction and engagement. For example, if learners are instructed to watch a lesson, summarise what they have seen and share it, for instance on an online forum or blog, it would be an example of testing whether they are in fact engaging with the content. This will break the imaginary dotted line boundary of the SAMR Model and illustrate a movement from enriching traditional classroom activities to a territory where the teaching and learning of mathematics are reliant upon technology, and the educational experience is transformed by the activity itself. This is something that happens in the Modification and Redefinition categories of the SAMR Model.

In the category Modification, technology allows the nature of the teaching and learning to change significantly and to be redesigned to fit a potentially different, richer outcome (Hamilton et al., 2016). Very few of the participants were functioning at this level. Only three of the 159 responses received fitted the example given for this category. They were:

- *'Learners can play with GeoGebra and make different discoveries.'*
- *'Allow learners to explore the connection between equations and graphs.'*
- *'Learners have GeoGebra on their tablets and use it themselves.'*

It should be noted that the emphasis here is on creating a predominantly learner-centred teaching and learning environment. The category Redefinition allows for the creation of previously inconceivable new tasks, a remix and redesign process, a total transformation of one's practice (Fabian and MacLean, 2014). The data collected did not provide any evidence of changes that would be affected at this level. It is worth noting that, according to Jude et al. (2014), Lund (2015), Myers (2014) and Puentedura (2012), Redefinition is the highest level of the SAMR Model and the most difficult to attain. In the study conducted by Burns-Sardone (2014), only 4.41% of the participating pre-service teachers could reach this level. A study undertaken by Nkonki and Ntlabathi (2016) looked at lecturers' use of one specific technology at an institution of higher education and revealed that the data collected provided no evidence of changes that could be linked to the Redefinition level.

***Research Questions 3 and 4***

To address RQ3 and RQ4 about whether there are significant differences in the ways that males and females (RQ3) and younger and older teachers (RQ4), view, integrate and use technology in the teaching and learning process, scores had to be computed for 'Availability of technologies', 'Technologies most frequently used in class for teaching', 'Technologies most frequently used for preparation' and 'Technologies most frequently used for personal development' in Table 2. For 'Availability of technologies' the options were '0 = No' and '1

= Yes'. Since there were 34 items listed, the minimum score for this variable is 0 (if no items were available), and the maximum score is 34 (if all items were available). For the other three variables, the values ranged from '1 = Never', '2 = Rarely', '3 = Sometimes', '4 = Often' and an average was computed for each variable. The closer the value to 1, the less the items were used, and the closer the value to 4, the more the item was used. A Shapiro-Wilk test was used to test the normality of the four scores, and since the p-value was less than 0.05 for each score, the data was not normally distributed, and nonparametric methods (Mann-Whitney (MW) test) were used for data analysis of these continuous scores.

To address RQ3 about whether there are significant differences in the ways that males and females view, integrate and use technology in the teaching and learning process, two statistical tests were run. For Table 1, where participants listed the technologies they felt had the most significant impact on the teaching and learning of mathematics, the two-proportions z-test was used to check for significant differences between the percentages reported by males and females. Since all p-values were greater than 0.05, no statistically significant differences were found between how males and females felt in terms of which technology had the most significant impact on the teaching and learning of mathematics. Note that, for conciseness, the p-values are not all listed here, since there are 20 categories listed in Table 1, which led to 20 p-values being generated. For Table 2 where participants explained how technology was being integrated in the teaching and learning process, the MW test was used and since the p-values for 'Availability of technologies' ($p = 0.344$), 'Technologies most frequently used in class for teaching' ($p = 0.600$), 'Technologies most frequently used for preparation' ($p = 0.374$) and 'Technologies most frequently used for personal development' ($p = 0.305$) were greater than 0.05, no statistically significant gender differences was found in the way they use and integrate ICT in their teaching.

To address RQ4 about whether there are significant differences in the ways that younger and older teachers view, integrate and use technology in the teaching and learning process, two statistical tests were run. For Table 1, where participants listed the technologies they felt had the most significant impact on the teaching and learning of mathematics, the two-proportions z-test was used to check for significant differences between the percentages reported by younger and older teachers. Since all p-values were greater than 0.05, no statistically significant differences were found between how younger and older teachers felt in terms of which technology had the most significant impact on the teaching and learning of mathematics. Note that, for conciseness, the p-values are not all listed here, since there are 20 categories listed in Table 1, which led to 20 p-values being generated. For Table 2 where participants explained how technology was being integrated in the teaching and learning process, the MW test was implemented and since the p-values for 'Availability of technologies' ($p = 0.372$), 'Technologies most frequently used in class for teaching' ($p = 0.852$), 'Technologies most frequently used for preparation' ($p = 0.427$) and 'Technologies most frequently used for personal development' ($p = 0.464$) were greater than 0.05, no statistically significant differences between younger and older respondents was found in the way they use and integrate ICT in their teaching.

## Discussion

### ***Top 10 technologies frequently used***

The top ten technologies that emerged in each category (see Table 2) could all be related to educational functionality. The personal computer / laptop was placed first in all four categories, followed by MS Word in two of the four categories, and the data projector and internet in the remaining two categories. This finding corresponds with the findings of other studies, for example, that of Chirwa (2018), who found that 83.2% of participants in their study used the internet for academic purposes. Another example is the study by Fraillon et al. (2014), who analysed the International Computer and Information Literacy Study (ICILS) 2013 data which is conducted across several countries and found that word-processing and presentation software were most widely used and that nearly one quarter of teachers used computer-based resources such as websites, wikis and encyclopaedias; for which one, of course, need a computer / laptop and the internet. In their research involving a group of mathematics teachers, Stols et al. (2015) also found that almost all the participants (95.2%) used their computers / laptops for teaching purposes either daily or weekly. Computers were also regularly used at home to prepare lessons, with almost 86% of the participants using their computers either daily (47.6%) or weekly (38.1%). According to Stols et al. (2015), teachers mostly used MS Word to prepare lessons and MS Excel to capture marks. A recent report from the Clayton Christensen Institute also found that the laptop was the hardware most frequently used by South African teachers (30.3%) (Fisher et al., 2017).

Although the findings of this study corresponded with findings reported on in previous relevant South African studies (Stols et al., 2015; Fisher et al., 2017), it was surprising to find that mobile devices did not feature among the top ten frequently used technologies. In this study, mobile devices such as cell phones and tablets, are listed as number fourteen. It is possible that the participants perceived the use of the internet, email and YouTube videos, which are often accessed on mobile devices, as mobile technology. It was interesting to note that the use of video-streaming services such as YouTube was among the top ten, especially for the teaching and learning of mathematics. This is an indication that the majority of teachers use video content in their teaching practice. Considering the poor TIMSS results of South Africa (Reddy et al., 2012; Reddy et al., 2016; HSRC, 2020), the use of videos could potentially improve the poor state of mathematics education in the country, provided that they are used in a pedagogically effective way. The researcher recommends that more research be undertaken in this field.

The introduction of the use of technologies such as the data projector, PowerPoint, the interactive board and dynamic mathematics software in the teaching of mathematics is a positive development as many literature studies indicate that it is of critical importance to increase visual images in mathematics education (Montenegro et al., 2018; Naidoo, 2012). However, this emphasis on visualisation, which was also prevalent in the SAMR classification, could lead to the misperception that technologies can be used only as visual aids in the classroom environment. The power of technology to differentiate and personalise education should not be underestimated. Moyle et al. (2012) found that learners consistently reported that they valued the possibility of personalising learning through the use of technologies that allowed them to control the pace and style of their learning. Furthermore, as can be seen in Table 1, participants in this study created many additional resources for use in the teaching and learning of mathematics. The fact that the internet was placed fourth on the 'for preparation' list shows that teachers are actively searching for valuable teaching resources, which in turn emphasises the importance of online mathematics projects such as the Mathematics Information and Distribution Hub (MIDHub) project for South African teachers of Mathematics (Stols et al., 2015).

### *The necessity for professional development*

Saal et al. (2020) conducted a case study to investigate the elements that facilitate and hinder the integration of educational technology in mathematics in economically disadvantaged areas of South Africa and concluded that policymakers need to provide teachers with continuous professional development on how to develop exercises and how to incorporate educational technology in mathematics that is in line with the pace of annual teaching plans. This view is supported by Liao (2018), who investigated the influence of professional development coaching on teachers' technology integration practices and concluded that more support from school leaders and administrators is needed to promote teachers' technology integration. While Liao's (2018) finding was made in a U.S. setting, a similar recommendation was made by Kruger (2018) in a South African setting. Perry (2018) studied the positive impact of professional development in Pennsylvania, USA, where resources and time were dedicated to technology training for teachers, and found that properly trained teachers were implementing technology in their classrooms. In a study by Iqbal (2017) in the Baltistan region the recommendation was to make teachers familiar with ICT and its use in teaching through different in-service training programs. In a study by Trujillo-Torres et al. (2020), where they investigated 73 high school teachers' perceptions of the introduction of ICT in Melilla, Spain, they found that teachers believed that training is essential to ICT integration in teaching and learning. The need for training in digital skills was also emphasized by Liesa-Orús et al. (2020). It was reported that a gap exists in respect of ICT skills and their use for pedagogical practices (Kit & Ganapathy, 2019). Teachers have to be technologically and pedagogically competent in the use of resources to be able to use them in their day-to-day teaching practice (Almerich et al., 2016; Buabeng-Andoh, 2012a).

## Conclusion

The explosion in the technology sector during the past two decades is increasingly affecting the lives of people in developing countries. However, despite the increasing availability of technology in emerging economies, teachers often do not make optimal use of the appropriate technologies for teaching and learning purposes (Livingstone, 2012; Mahdum et al., 2019). As mentioned earlier, large amounts of money are being invested in equipping South African schools with technology; however, there is little evidence of the effective use of these technologies for instruction. Saal et al. (2020) conducted a case study to investigate the elements that facilitate and hinder the integration of educational technology in mathematics education in economically disadvantaged areas of South Africa and concluded that policymakers need to provide teachers with continuous professional development on how to develop exercises and how to incorporate educational technology in mathematics that is in line with the pace of the annual teaching plans. This view is supported by Liao (2018), who investigated the influence of professional development coaching on teachers' technology integration practices and concluded that more support from school leaders and administrators is needed to promote teachers' technology integration practice. Liao's (2018) finding was made in a United States setting, but a similar recommendation was made by Kruger (2018) in a South African setting. Perry (2018) studied the positive impact of professional development in Pennsylvania, USA, where resources and time were dedicated to technology training for teachers, and found that properly trained teachers were implementing technology in their classrooms. In a study by Iqbal (2017) in the Baltistan region the recommendation was also to make teachers familiar with ICT and its usage in teaching through different in-service training programmes. In a study by Trujillo-Torres et al. (2020), where they investigated 73 high school teachers' perceptions of the introduction of ICT in Melilla, they found that teachers believe that training to essential to ICT integration in teaching and learning. The need for training in digital skills is also emphasised by Liesa-Orús et al. (2020).

The data collected for this research emphasised the importance of creating professional development programmes that focus on training teachers to enable them to make fundamental pedagogical shifts when integrating technology in their classrooms. Teachers should not only understand the functions of a specific technology, but should also know how it can be integrated in a way that will ensure improved learning outcomes. Even as recently as last year it was reported that a gap exists in respect of ICT skills and their use for pedagogical practices (Kit & Ganapathy, 2019). Teachers have to be technologically and pedagogically competent in the use of resources in order to be able to use them in their day-to-day teaching practice (Almerich et al., 2016; Buabeng-Andoh, 2012a).

More than a decade ago, the International Education Advisory Board announced that effective teachers who possess the necessary pedagogical knowledge to integrate technology in their teaching would be the most prolific teachers in the 21st century (International Education Advisory Board, 2008). This study found that it is essential to find ways to motivate mathematics teachers to use technologies as a substitute for traditional teaching methods and encourage pedagogical change and improve conceptual understanding in the teaching and learning of the subject mathematics. There has been a lot of efforts to promote conceptual uses of technology in the teaching of mathematics. There is no need to tailor-make the training for males and females, respectively, for a younger and older age group, specifically, since this study found no statistically significant differences in ICT use between males and females and between younger and older teachers. The National Council of Teachers of Mathematics (NCTM) recommends that learners use technology to concentrate on problem-solving processes rather than on calculations related to the problems (Ittigson & Zewe, 2003). The position held by the NCTM is, "It is essential that teachers and students have regular access to technologies that support and advance mathematical sense-making, reasoning, problem-solving, and communication. Effective teachers optimize the potential of technology to develop students' understanding, stimulate their interest, and increase their proficiency in mathematics. When teachers use technology strategically, they can provide greater access to mathematics for all students" (NTCM, 2015, p. 1). This fundamental and essential shift in teacher pedagogy could be attained through professional development programmes that model functional pedagogical changes to teachers and could lead to improved mathematics education in South Africa.

**Declaration of interest statement**

There is no conflict of interest.

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