Integrating Educational Technology in Mathematics Education in Economically Disadvantaged Areas in South Africa

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Abstract

This qualitative case study adopted the Unified Theory of Acceptance and Use of Technology (UTAUT) created by Venkatesh, Morris, Davis, and Davis (2003) to investigate the elements that facilitate and hinder the integration of educational technology in mathematics education in economically disadvantaged areas of South Africa. Semi-structured interviews were conducted with two school leaders and three Grade 5 mathematics teachers from two Smart Schools, one in Gauteng and the other in the Western Cape Province, which were conveniently and purposefully selected. Additionally, one mathematics lesson was observed at each of these schools. To analyse the responses from the interviews, content analyses were used. Findings showed that facilitating conditions such as adequate technological infrastructure and qualified Information Technology technicians influenced the actual use of educational technology in mathematics instruction. However, social influence had the largest impact on these teachers' integration of educational technology in mathematics education. Implications for practice are discussed.

Keywords: economically disadvantaged areas, educational technology, mathematics education, primary education, UTAUT, qualitative.

Introduction

Quality education is regarded as a fundamental factor that improves the economic development of a country (Schwab, 2017). Consequently, several countries resorted to integrating technology in an attempt to improve the quality of education in schools (Heyberi, 2012; Rana, 2017). This resulted in the development of national policies focusing on technology integration in education (Mukhari, 2016). The Department of Education (DoE) in South Africa developed the White Paper on e-Education policy, indicating that Information Communication Technology (ICT) can potentially improve the quality of teaching and learning (Department of Education [DoE], 2004). In response, the Gauteng Department of Education (GDE), as well as the Western Cape Education Department (WCED), launched various ICT initiatives known as paperless or smart-classrooms in their provinces. These projects were mostly implemented in poor schools located in economically disadvantaged areas (Lesufi, 2014; Zille, 2015). Some of the schools in these areas were equipped with educational technology, such as smart boards, tablets and laptops, which required substantial capital investments (Gina & Kubayi, 2016).

Despite these investments to improve the quality of education, the poor mathematics performance of the learners in international assessments, such as the Trends in Mathematics and Science Study (TIMSS) (Mullis, Martin, Foy, & Hooper, 2016), as well as the low level of ICT integration in schools (Kruger, 2018), seems to remain a primary concern for the DoE. The literature reviewed showed that most of the South African mathematics teachers do not optimally use, or successfully implement educational technology in mathematics instruction (Cassim, 2010; Howie & Blignaut, 2009; Kruger, 2018; Stols et al., 2015). In fact, some researchers found that most mathematics teachers do not use educational technology during their mathematics lessons at all (Saal, 2017; Umugiraneza, Bansilal, & North, 2018). Some educational researchers argue that educational technology can improve the performances of learners if correctly implemented (Ferraro, 2018). Recent studies on the integration of educational technology in mathematics reported mostly on the current practices and barriers to the integration of computers in mathematics education (Cassim, 2010; Khomo, 2018; Stols et al., 2015; Umugiraneza et al., 2018). These were mostly quantitative secondary data analysis studies. A limited number of studies focussed specifically on educational technology integration in economically disadvantaged areas (Chigona, Chigona, & Davids, 2014).

So far, very little attention has been paid to Grade 5 mathematics teachers in economically disadvantaged areas who integrated technology in their mathematics classrooms. Consequently, this qualitative study investigates the elements that facilitate the integration of educational technology in mathematics teaching and learning in economically disadvantaged areas. The use of educational technology was investigated in two Smart Schools in South Africa in two different provinces, and the focus was on the current practices and competencies of mathematics teachers who use educational technology in mathematics education in economically disadvantaged areas. The study also explored how these teachers perceived the use of educational technology and what they considered as hindering factors that influenced their integration of educational technology in mathematics education.

Literature Review

Facilitating conditions, or enablers for the integration of educational technology in mathematics teaching and learning, can be described as determinants that aid and encourage teachers to successfully use it in their classrooms (Cubukcuoglu, 2013). An earlier study by Ertmer, Addison, Lane, Ross, and Woods (1999) grouped these enablers into two categories, namely, school factors and teacher factors.

Facilitating Conditions at School-level

These enablers mostly refer to the conditions and technological infrastructure, which support teachers in the process to integrate educational technology in the school. These conditions include, but are not limited to, adequate computers and tablets (Heyberi, 2012), unrestricted access to use computer rooms/laboratories and up to date and compatible mathematical software (McCulloch, Hollebrands, Lee, Harrison, & Mutlu, 2018). Moreover, reliable internet connection (Ouma, Awuor, & Kyambo, 2013) and policies on how to use educational technology specifically for mathematics (Khomo, 2018; Nelson, Voithofer, & Cheng, 2019), were also found to be influential in facilitating the integration of educational technology in teaching and learning. Researchers, such as Bingimlas (2009), as well as Wachira and Keengwe (2011), also found that sufficient support (technical, training, administrative) and adequate time, promote the use of educational technology in the classroom. It is worthy to note that the facilitating conditions will differ per school based on the current hindering factors that they experience. The literature review also showed that the facilitating conditions are somehow interrelated and sometimes, two or more factors need to be in place for teachers to use educational technology (Bingimlas, 2009; Wachira & Keengwe, 2011). For instance, Bingimlas (2009) explains that for teachers to integrate educational technology in their classrooms successfully, schools need to provide:

- Teachers with hardware and software;
- Training courses on how to use new technologies;

- Sufficient time by decreasing the number of periods a day or increasing the time allocated for a period and;
- Continuous technical support.

These findings are supported by Wachira and Keengwe (2011) who explained that facilitating conditions, such as sufficient technology and "training in appropriate pedagogy using tools and in administration and technical support" (p. 25), need to be provided concurrently for teachers to use educational technology confidently in their classrooms.

Facilitating Conditions at Teacher-level

Facilitating conditions at teacher-level are mostly associated with the teachers' beliefs and skills (Heyberi, 2012). For instance, teachers with positive attitudes and beliefs will most likely use educational technology in teaching and learning (Cubukcuoglu, 2013). Teachers would need continuous support and training to develop positive attitudes and to change their perceptions regarding the use of educational technology in teaching (Agyei & Voogt, 2011). However, Kafyulilo, Fisser, and Voogt (2016) found that even though most of the pre-service teachers from Tanzania had positive perceptions of educational technology, their integration thereof was still low. Continuous support and training might also equip or improve the technical competency and knowledge of teachers, which in turn will improve their confidence and therefore teachers might be more willing to integrate educational technology in their classrooms (Eickelmann, 2011). Correspondingly, Xiang (2018) found that competency and knowledge of teachers from China and England are regarded as important factors that facilitate their use of educational technology. This finding is further supported by Goktas, Gedik, and Baydas (2013), who found a similar result. Bingimlas (2009) also explained that even if enablers, such as support and training are provided to teachers, they should go the extra mile by "taking advantage of resources offered at schools, being open minded towards new ways of teaching, taking up opportunities for training offered at school and relying on themselves to be able to solve problems in their use of ICT" (p. 243).

Interestingly, several researchers found positive correlations between perceptions about ease of use and teachers' integration of educational technology, meaning teachers will only use technology in their classrooms if it doesn't require a lot of effort. This also points back to relevant training and continuous support since teachers need to be equipped with the necessary skills and knowledge to use educational technology in their classrooms.

Research questions

The purpose of this qualitative case study was to explore the elements that facilitate and hinder the integration of educational technology in mathematics teaching and learning in economically disadvantaged areas of South Africa. The subsequent section shows the research questions that guided the study.

- Which elements facilitate the successful integration of educational technology in mathematics education in economically disadvantaged areas?
- What are the current practices and competencies of mathematics teachers who use educational technology in mathematics education in these areas?
- How do teachers in economically disadvantaged areas perceive the use of educational technology?
- What, if any, are the hindering factors influencing the mathematics teachers' integration of educational technology in these areas?

Method

This study is rooted in the implementation of the e-Education policy of South Africa in particular, and the initiatives undertaken by the GDE and the WCED, respectively (Department of Education [DoE], 2004). The Gauteng and the Western Cape Province are two of the leading provinces in South Africa in terms of their Grade 5 learners' performance in TIMSS 2015 (Mullis et al., 2016). The learners from the Western Cape Province achieved an average mathematics score of 441 while those from the Gauteng Province achieved an average mathematics score of 420 out of a possible 1 000 points (Reddy et al., 2016). The Gauteng Province also recently claimed the second place in the country for the National Senior Certificate (NSC) examination 2019 pass rate (87.2%) while the Western Cape Province produced an NSC pass rate of 82.3% placing the province fourth amongst the country's nine provinces (Department of Basic Education [DBE], 2020). Furthermore, the Western Cape Province is also well known for its implementation of the Khanya Project (van Wyk, 2011). This project was launched in 2002 and aimed to provide schools with technology, prior even to the finalisation of the e-Education policy (Sadeck, 2016). The context of the study is situated within the GDE's Future Schools project (Lesufi, 2014), as well as the eLearning Game Changer project of the WCED (Zille, 2015) which were initiated in fulfilment of the paperless or smart-classroom project. In short, these projects provided selected schools, mostly in economically disadvantaged areas, with educational technology, accompanied by training for teachers on the use of these technologies (Western Cape Education Department [WCED], 2019).

Participants and Sampling

This qualitative multiple case study used an interpretive naturalistic approach (Denzin

& Lincoln, 1994) to study the elements that facilitate the use of educational technology in mathematics education. Non-probability sampling methods, such as purposive and convenience sampling were employed because the population was hard to locate (Maree, 2012). Christensen, Johnson and Turne (2014) explain that "a researcher specifies the characteristics of the population of interest and then locates individuals who have those characteristics when employing purposive sampling" (p. 171). Convenience sampling refers to "situations when population elements are selected based on the fact that they are easily and conveniently available" (Maree, 2012, p.177). The Gauteng and Western Cape provinces of South Africa were purposefully selected because these provinces have recently initiated projects focussing on educational technology (Christensen et al., 2014). Thereafter, convenient sampling was employed to select one school per province that benefitted from these projects, that were also located in an economically disadvantaged area and which were geographically accessible. The principal from the school in the Western Cape and the deputy principal from the school in Gauteng were then purposefully selected to provide insights on how educational technology is implemented in each school, respectively. The principal from the school in Gauteng was not available to be interviewed and recommended the deputy principal instead. Afterwards, one male (Gauteng) and two female (Western Cape) teachers who taught Grade 5 learners were purposefully selected. The authors had no previous relationships with the participants. Consequently, these teachers were identified by their principals because they used educational technology in Grade 5 mathematics classes and were readily available to participate in the study.

Data Collection

Semi-structured interviews and non-participatory classroom observations were employed in this study. The interviews were conducted face-to-face at a time that was convenient for the participants and were digitally recorded. The duration of the interviews ranged between 20 and 40 minutes each. One mathematics lesson per school was observed and an observation checklist was completed for each.

Data Analysis

The audio recordings were transcribed verbatim. The school in Gauteng was referred to as School A and the school in the Western Cape, School B. The data were coded as follows: the male deputy principal from School A is Participant 1, the male principal from School B is Participant 2, the male teacher from School A is Participant 3, and the female teachers from School B were referred to as Participant 4 and Participant 5, respectively. Directed content analysis was employed by coding data with predetermined as well as new codes that were derived from the data (Hsieh & Shannon, 2005).

Trustworthiness

The interview transcripts were e-mailed to the participants for member checking and comments. To further enhance the credibility of the study, multiple sources (methodological triangulation), such as semi-structured interviews and non-participatory classroom observations, were employed. The authors were involved in the data analysis process to ensure the objectivity and accuracy of data. Confirmability was further ensured by providing an audit trail. For instance, transcriptions, audio recordings, instruments were made available to all participants.

Findings

In this section, the findings of the study are discussed according to the UTUAT theoretical framework, as described in Venkatesh et al. (2003).

Performance Expectancy

All five participants believed that the use of educational technology encourages learners to develop problem-solving strategies, changes the attitude of learners towards mathematics, as well as make learners more creative in solving problems. Participant 5 explained: “I’ve got learners in my class who don’t like maths at all but give it [mathematics] to them on a device and they’ll be like, ‘Ms, I’ll do the exercise’”.

This finding is consistent with the results of Stols et al. (2015), who found that teachers believe that online instructional resources improve the learners’ understanding of mathematics and encourage learner interaction. Likewise, Jehlička and Rejsek (2018) concluded that primary school learners’ understanding of mathematics could improve if they interpret results derived from educational technology correctly. Other beliefs regarding the effects of educational technology on learner performances also emerged, as one participant (Participant 3) felt that educational technology has a positive effect on his learners’ marks. He explained that educational technology provides learners with a variety of approaches to learning since they all learn differently. Participant 5 elaborated that educational technology includes visuals and sounds which “… improves the learners’ performance drastically”.

Another participant (Participant 4), disagreed with this notion, saying that while educational technology engages her learners, it does not have an effect on their marks. Participant 4 believed that educational technology could only have a positive influence on the marks of learners if internet restrictions were in place. She explained: “The learners… just want to go Google inappropriate content. They must just do quizzes ... then it can help”.

These teachers seem to perceive educational technology as potentially useful and are realistic about the potential of educational technology to improve their teaching strategies and the results of their learners. However, some teachers have not yet seen the anticipated return on investment, and they identified areas of concern, such as the lack of internet restrictions. This issue might have not yet been fully addressed.

Effort Expectancy

Effort expectancy in this study implied that the use of educational technology in the teaching and learning process is easy, and therefore, it might have influenced the teachers' intention to integrate educational technology in mathematics. In contrast with one of the findings of Khlaif (2018), who found low effort expectancy to be the strongest predictor of K-12 teachers' behaviour intention to integrate mobile technologies in classroom instruction, no evidence was found in this study that indicates that these teachers use technology in instruction because it is easy to use. This might be because the use of technology in instruction is still in the "teething phase" as Participant 5 explained. She explained that it was "rough" using Green Shoots Maths Curriculum Online (MCO), which is aligned with the South African curriculum (CAPS) for the June examination. She said:

> Literally the morning of the exams we would still be running around to each other saying, 'We need to change this part. We need to go change that part. You missed this. I found this bug. I found this problem'. And then we would have to sit and figure out … It was crazy. (Participant 5)

It is safe to say that these teachers at School B found the use of educational technology overwhelming. This could be linked to the teachers' limited technical knowledge, as shown in the next comment: "… Some nights I'm up … the whole night just watching tutorials just to understand how a program works". (Participant 4)

Consequently, a strong desire for continuous professional development was noted by all the mathematics teachers to advance their current technical skills and knowledge, as shown in the next comment: “I need at least two workshops a month to help me cover the curriculum through the use of technology… I think the workshops will help me to grow because right now I'm using my own knowledge and experience”. (Participant 3)

Social Influence

Findings showed that social influence was linked to the teachers’ intention to use educational technology in mathematics lessons the most. These schools were selected by the respective education departments to pilot the use of educational technology, such as computers, tablets and smartboards as explained in the next comments:

- “The school was chosen by the Member of the Executive Council [MEC]. It’s actually a pilot school. We are piloting the implementation of smart boards and tablets in the classroom”. (Participant 1)
- “… Our school was identified as a model [pilot] school to receive all these tablets”. (Participant 2)

This means that teachers did not volunteer or actively pursue the use of educational technology in their classrooms by themselves. For example, Participant 5 explained that they were instructed by the principal (Participant 2) to use educational technology in their classroom. Another teacher, Participant 4, also indicated that they “have to” attend workshops focussing on educational technology, especially on “Saturdays” because they are a “model” school. Thus, the principals of these schools ensured that all teachers use these devices in teaching and learning. This finding contradicts that of Stols et al. (2015) who found no effect between social influence and behaviour intention. This finding supports that of Venkatesh et al. (2003) who found that social influence has a stronger effect on behavioural intention in mandatory environments.

Facilitating Conditions

The facilitating conditions differed between the two schools under investigation. Starting with School A (Gauteng), all the classrooms in this school were furnished with smart boards. However, at the time of the data collection, only the Grade 7 learners were using tablets. Participant 1, explained that the GDE is prioritising the implementation of tablets in secondary schools, strangely enough, starting with Grade 7's. He felt as if the GDE forgot about their school since they were still waiting for the tablets for Grades 4, 5 and 6 to be delivered. The lack of facilitation conditions in this school thus limited the actual use of tablets in the Grade 5 mathematics classroom, since the learners have not yet received their tablets at the time the interview was conducted. For School B (Western Cape), every Grade 5 learner was equipped with a tablet, whilst all the teachers were equipped with laptops and had shared use of eBeams, as well as visualizers.

Contrasting responses emerged regarding the WiFi connection at both schools. All the participants at School A and Participant 2 from School B described the WiFi connection as excellent. On the other hand, Participant 4 explained: “The … WiFi is a problem, it's very slow and on and off all the time”. While Participant 5 laughed and explained that the WiFi connection is “… terrible… the WiFi connection was amazing for the first half of the year [2018], and when we came back to school, we had no WiFi for about three weeks or so”.

A strong support system is also one of the factors which reportedly aids the integration of educational technology. School A had one IT intern at the school to assist the teachers. The deputy principal (Participant 1) expressed his dissatisfaction in the following comment: “The GDE has provided us with an intern and his skills are not that good. We don't have a qualified technician who is stationed at the school to assist with technological challenges.

Focussing on School B, participants explained that they have the assistance of four IT technicians. Two of the participants did not have any problems with the skills of these technicians, even though they were also interning. For instance, Participant 2 explained that the teachers learned from the IT interns how to solve small technical glitches on their own, as shown in the next comment:

> I've … made it clear to teachers that they must also learn from these interns in terms of what to do when something happens. And, I see that the IT staff is not used as much anymore, because teachers have become very much capable of handling little [technical] problems on their own. (Participant 2)

However, Participant 5 at School B differed as she regarded the technical support as “… not really efficient but at least there’s someone…it’s a face”. The response time of IT technicians at School B was also an issue. Participant 5 stressed:

> Yoh! It takes a while [for the technician to respond]. We have one IT technician for almost 32 teachers. So, if I need someone now to come because something is wrong with the WiFi, he might already be with another teacher. And he already has two other teachers waiting for him. So, I’ll see him in a day’s time or two days. (Participant 5)

She explained that her laptop crashed while the technicians were trying to fix it and it had to be sent away. Participant 5 clarified: “I just got my computer yesterday [the day before the interview]. It’s like two months later. I had to kind of cope without it”. Teachers are forced to return to the traditional method of instruction when technical failures arise, as expressed in the following comment: “…If there’s a technological failure and I don’t have the tools to explain, then I’ll just go back to the board”. (Participant 5)

Based on the above discussion it is clear that facilitating conditions, such as favourable teacher-IT technician and learner-IT technician ratios, sufficient tablets, reliable WiFi connection, good quality mathematics software, continuous professional development opportunities specifically for educational technology integration in mathematics, as well as online security measures, influence the use behaviour of mathematics teachers. This finding supports previous studies that found a positive relationship between facilitating conditions and use behaviour (Wang, Tigelaar & Admiraal, 2019).

Behavioural Intention

According to the UTAUT model, as explained by Venkatesh et al. (2003), the performance expectancy, effort expectancy and social influence are key determinants of an individual’s behaviour intention. However, in this study, only performance expectancy and social influence affected the behaviour intention of these teachers. In line with the findings of Šumak and Šorgo (2016), this study concludes that social influence can be regarded as the construct that influenced the participants’ intent to use educational technology the most. As explained earlier, the mathematics teachers’ use of educational technology for teaching and learning purposes was not voluntary. As stated by the UTAUT model, behaviour intention predicts actual behaviour. As assumed, the behavioural intention influenced the actual behaviour of these participants.

Actual Use

All the mathematics teachers who participated in the study used educational technology in their classrooms because these schools piloted the use of educational technology. One participant (Participant 3) used YouTube as a reinforcement tool, as well as to develop low, middle and higher-order thinking skills as expressed in the following comment: “I'm playing videos to reinforce what I taught. I will start with lower-order problems that everyone can understand and when everyone is engaged, then I continue with middle order and higher-order problems”. Another participant used YouTube videos, but this time as a substitute teaching method, as illustrated in the following comment:

> I will go to a YouTube video to show them a different method on how to solve mathematics problems. Maybe they don't understand the way I'm teaching but I'll find another teacher [on YouTube] that can assist them to solve the problem. (Participant 4)

All participants used educational technologies for communication purposes. For instance, Participant 1 explained that Dropbox made it easier to share learning material and ideas with other teachers, while Participant 4 and Participant 5 used Google classroom to share ideas, to assist each other, and to communicate with their learners. These participants also used the Green Shoots MCO for weekly exercises, as well as for the administration of the June mathematics examination.

In this study, most participants had positive perceptions on the use of educational technology and used educational technology in their classroom, despite the existing barriers, such as poor WiFi connection, the lack of qualified IT technicians and lacking in continuous professional development opportunities. Furthermore, social influence affected the participants' intention to use educational technology the most, which in turn influenced their actual use thereof in mathematics education.

Addressing the Research Questions

In response to the question about which elements facilitate the successful integration of educational technology in mathematics education in economically disadvantaged areas, we found that schools should have sufficient technological infrastructure, such as tablets, a reliable WiFi connection, as well as mathematics software for teachers to use for instructional purposes. Furthermore, teachers and principals with positive perceptions regarding the use of educational technology tend to use it more. Teachers need to advance their basic technical skills to use educational technology more effectively and should have the services of qualified onsite IT technicians readily available in the event of technical failures. The teacher-IT technician, as well as the IT technician-learner ratio, should be favourable to ensure that teachers and learners have devices which are functional during lessons. Additionally, we found that teachers should be provided with continuous professional development opportunities to assist teachers on how to use educational technology optimally and how to develop technology-infused exercises in mathematics. Lastly, security or preventative measures should be in place when learners use the internet to prevent distractions from the online environment that could interfere with the teaching and learning process.

In relation to the question about the current practices and competencies of mathematics teachers who use educational technology in mathematics education in economically disadvantaged areas, findings showed that these teachers mostly used YouTube as a reinforcement tool, to develop low, middle and higher-order thinking skills, and as a substitute teaching method. Teachers, furthermore, used mathematical software, such as Quizzes to improve mathematics results, as well as Green Shoots MCO for assessment purposes. Teachers also used Dropbox, as well as Google classroom for communication and storage purposes.

How do these teachers perceive the use of educational technology? All participants had mostly positive perceptions regarding the use of educational technology. These teachers believed that educational technology engages and encourages learners to develop different and creative approaches to solve problems. They believed that educational technology has the potential to change the attitude of learners towards mathematics, as well as making learners creative in solving problems. Most teachers believed that educational technology influences the mathematics performance of learners. Others cautioned that educational technology could only have a positive influence on the learners' mathematics performance when security or restrictive measures are in place, preventing learners from visiting websites with inappropriate content.

With the focus on the question about the hindering factors influencing these teachers' integration of educational technology in these areas, results showed that a lack of technological infrastructure, such as adequate tablets, eBeams, and visualizers hindered the use of educational technology. Furthermore, a weak WiFi connection as well as technical failures disrupted learning and forced teachers to resort back to traditional methods of teaching. The lack of continuous professional development focusing on how to use educational technology in mathematics sometimes discouraged the teachers from using it, because they struggled to keep up with the continuously evolving technology. Furthermore, the lack of sufficient and well-qualified onsite IT technicians also emerged from the findings. The fact that some of the IT technicians who were deployed to schools were not competent in solving typical technical problems resulted in long waiting periods, not only just for senior IT technicians to arrive but also for the devices, which had to be sent elsewhere for repairs.

Conclusion

The purpose of this study was to determine the elements that facilitate and hinder the successful integration of educational technology in mathematics education in economically disadvantaged areas. The UTAUT model was selected as the theoretical framework underpinning this study since it could explain the behaviour of mathematics teachers regarding the integration of educational technology in instruction. Several findings emerged, however, the main finding of this study is that mostly social influence influenced the actual use of educational technology in mathematics instruction. This study was limited to one smart school in the Gauteng Province and one smart school in the Western Cape province of South Africa. Consequently, future studies could make use of multiple comparative case studies to collect data from all the Smart Schools in each province to see if the goals outlined by these projects have been met.

This study contributes to the literature on mathematics teachers' current practices and perceptions of using educational technology plus the barriers and facilitating conditions for the integration of educational technology. 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. For example, if the latter concentrates on fractions, then the training should focus on how to develop exercises and how to teach fractions using educational technology effectively.

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